IEC/IEEE 61886-1

Edition 1.0 2021-04

INTERNATIONAL STANDARD

colour inside

Subsea equipment –
Part 1: Power connectors, penetrators and jumper assemblies with rated voltage from 3 kV (U_{max} = 3,6 kV) to 30 kV (U_{max} = 36 kV)

IEC/IEEE 61886-1:2021-04(en)

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

ICS 47.020.60

ISBN 978-2-8322-9623-3

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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This publication is published as an IEC/IEEE dual logo standard.

The text of this standard is based on the following IEC documents:

FDIS	Report on voting
18/1710/FDIS	18/1716/RVD

Full information on the voting for the approval of this document can be found in the report on voting indicated in the above table.

International standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

A list of all parts in the IEC/IEEE 61886 series, published under the general title *Subsea equipment*, can be found on the IEC website.

The IEC Technical Committee and IEEE Technical Committee have decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

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INTRODUCTION

Within the oil and gas industry there is an increasing use of electrical power equipment on the seabed. Subsea processing activities like compression and pumping require increasingly higher amount of electrical power. Power generation, whether onshore or offshore, requires development of equipment both for subsea transmission and distribution.

Current standards for topside equipment do not include requirements related to equipment installed below the sea surface. Project and client specific specifications are used for both design and testing. The fact that equipment is qualified on a project basis, rather than to common standards, has several drawbacks:

- similar equipment is qualified to different type and routine test specifications;
- equipment has to be re-qualified for new projects that have slightly different requirements, for instance increased water depth;
- project specific ratings leading to higher number of equipment versions than strictly required.

All these issues lead to increased costs and schedule (for type testing), and also increased risk for failure (several type test programs are performed on a high number of various designs). By standardizing tests and implement continuous improvement on fewer products, this risk will be reduced in the long term.

The SEPS JIP (Subsea Electrical Power Standardization Joint Industry Project) was established in 2010 by seven oil and gas companies, with the aim to develop common operator standards for subsea electrical power equipment and systems and support further development of these into internationally recognized standards. This document is developed upon base material by SEPS. The aim for the SEPS JIP is to contribute to the development of IEC/IEEE dual logo standards; hence both IEC and relevant ANSI/IEEE standards are referenced where applicable. Relevant equipment manufacturers have contributed with review and comments to the document.

The lack of accessibility (for repair or replacement) defines strict requirements to reliability, beyond what is normally seen in topside applications.

As subsea equipment in many cases is interconnected to topside equipment, specifications for subsea equipment are considered to be within the scope of IEC TC 18 – Electrical installations of ships and of mobile and fixed offshore units.

SUBSEA EQUIPMENT –

Part 1: Power connectors, penetrators and jumper assemblies with rated voltage from 3 kV (U_{max} = 3,6 kV) to 30 kV (U_{max} = 36 kV)

1 Scope

This document is applicable to single and three-phase wet-mateable and dry-mateable AC connectors, penetrators and jumper assemblies with rated voltages from 3 kV (U_{max} = 3,6 kV) to 30 kV (U_{max} = 36 kV). This document relates to the requirements and tests for products in the "as manufactured and supplied" condition. This document is not applicable to requirements and tests for products that have been subsequently installed, deployed or retrieved.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60060-1, *High-voltage test techniques – Part 1: General definitions and test requirements*

IEC 60156, *Insulating liquids – Determination of the breakdown voltage at power frequency – Test method*

IEC 60243-1:2013, *Electric strength of insulating materials – Test methods – Part 1: Tests at power frequencies*

IEC 60270, *High-voltage test techniques – Partial discharge measurements*

IEC 60721-3-2:2018, *Classification of environmental conditions – Part 3: Classification of groups of environmental parameters and their severities – Transportation and handling*

IEC 60885-3, *Electrical test methods for electric cables – Part 3: Test methods for partial discharge measurements on lengths of extruded power cables*

IEC 60986, *Short-circuit temperature limits of electric cables with rated voltages from 6 kV (U_m = 7,2 kV) up to 30 kV (U_m = 36 kV)*

IEC 61238-1-3:2018, *Compression and mechanical connectors for power cables – Part 1-3: Test methods and requirements for compression and mechanical connectors for power cables for rated voltages above 1 kV (U_m = 1,2 kV) up to 30 kV (U_m = 36 kV) tested on non-insulated conductors*

IEC 61442, *Test methods for accessories for power cables with rated voltages from 6 kV (U_m = 7,2 kV) up to 30 kV (U_m = 36 kV)*

IEC 62262, *Degrees of protection provided by enclosures for electrical equipment against external mechanical impacts (IK code)*

ISO 7326:2016, *Rubber and plastics hoses – Assessment of ozone resistance under static conditions*

ISO 12103-1, *Road vehicles – Test contaminants for filter evaluation – Part 1: Arizona test dust*

ISO 23936-2:2011, *Petroleum, petrochemical and natural gas industries – Non-metallic materials in contact with media related to oil and gas production – Part 2: Elastomers*

ISO 30013:2011, *Rubber and plastics hoses – Methods of exposure to laboratory light sources – Determination of changes in colour, appearance and other physical properties*

ANSI/ICEA T-27-581/NEMA WC 53, *Standard Test Methods for Extruded Dielectric Power, Control, Instrumentation, and Portable Cables for Test*

ANSI/API Spec 6A:2018, *Specification for Wellhead and Christmas Tree Equipment*

ANSI/NEMA WC 74 ICEA S-93-639, *5-46 kV Shielded Power Cable for Use in the Transmission and Distribution of Electric Energy*

ANSI/NEMA WC 71 ICEA S-96-659, *Standard for Non-shielded Cables Rated 2001-5000 Volts for Use in the Distribution of Electric Energy*

ASTM D877, *Standard Test Method for Dielectric Breakdown Voltage of Insulating Liquids Using Disk Electrodes*

ASTM D1141-98, *Standard Practice for the Preparation of Substitute Ocean Water*

ASTM D1169, *Standard test method for Specific Resistance (Resistivity) of Electrical Insulating Liquids*

ASTM D1816, *Standard Test Method for Dielectric Breakdown Voltage of Insulating Liquids using VDE Electrodes*

EN 10204, *Metallic products – Types of inspection documents*

IEEE Std 386, *Separable Insulated Connector Systems for Power Distribution Systems Rated 2,5kV through 35kV*

IEEE Std 4, *Standard for High Voltage Testing Techniques*

NORSOK M-710:2014, *Qualification of Non-Metallic Sealing Materials and Manufacturers*

3 Terms, definitions and abbreviated terms

For the purposes of this document, the following terms and definitions apply.

ISO, IEC and IEEE maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp
- IEEE Standards Dictionary Online: available at http://dictionary.ieee.org

3.1 Terms and definitions

3.1.1
cable termination
device fitted to the end of a cable to ensure electrical connection with other parts of the system and to maintain the insulation up to the point of connection

3.1.2
connector assembly
assembly of wet and/or dry mate connectors, penetrators, cable terminations, cable pigtails or jumper cables between subsea components – or any combination of these

3.1.3
connector
fully insulated termination permitting the connection and the disconnection of a cable to other equipment

3.1.4
de-mate
dis-connection of separable connectors so that all electrical, mechanical and environmental sealing functions are fully dis-engaged

3.1.5
differential pressure
difference between the two values of absolute pressure that are acting on either side of a wall or partition

3.1.6
dry mateable connector
connector designed to be submerged in sea water but connected/disconnected in a dry (topside/onshore) environment only – with no voltage or current applied

3.1.7
dummy connector
device allowing connection to a connector half for long term protection when submerged and unmated

Note 1 to entry: Normally, no cable is attached to the dummy connector; internal connection between phases may however be established to allow continuity testing.

3.1.8
inner water seal
water seal closest to the conductor

3.1.9
jumper assembly
cable connection terminated at each end to either a connector or a penetrator

Note 1 to entry: The term includes the connector assembly at both ends, the cable, the protective fluid filled hose and the hose terminations, as applicable.

Note 2 to entry: Other common designations are electrical flying lead and electrical jumper lead

3.1.10
mate
connection of separable connectors so that all electrical, mechanical and environmental sealing functions are fully engaged

3.1.11
misalignment
misalignment between two connector halves in a connector pair which is expressed by means of the following definitions:

- axial misalignment;
- radial misalignment;
- angular misalignment;
- rotational misalignment

3.1.11.1
axial misalignment
amount of offset from a nominal central datum in a direction parallel to the axes of two connector halves

Note 1 to entry: The axial misalignment is normally expressed in millimetre.

3.1.11.2
radial misalignment
amount of offset between the two axes of two cylindrical connector halves in a direction perpendicular to the axes

Note 1 to entry: The radial misalignment is normally expressed in millimetre.

3.1.11.3
angular misalignment
angle formed at the intersection of two axes of two cylindrical connectors halves

Note 1 to entry: The angular misalignment is expressed in degrees.

3.1.11.4
rotational misalignment
amount of circumferential offset about the axes of two connector halves

Note 1 to entry: The rotational misalignment is expressed in degrees.

3.1.11.5
maximum misalignment capability
maximum degree of misalignment that a connector can tolerate without malfunction, expressed by the maximum values of combined axial, radial, angular and rotational misalignment

Note 1 to entry: The values of axial, radial, angular and rotational misalignment when combined to produce maximum misalignment capability may be less than each misalignment taken singularly. It is therefore not sufficient to determine the maximum misalignment capability by measuring each singular component in turn.

3.1.12
onshore protection cap
device connected to a connector half during handling, transportation and storage

Note 1 to entry: The cap is to protect against ingress of particles and the sealing surfaces against mechanical damage.

3.1.13
outer water seal
water seal closest to the conductive media

3.1.14
penetrator
device that enables one or several conductors to pass through a partition such as a wall or a tank and insulates the conductors from it

Note 1 to entry: The means of attachment, flange or fixing device to the partition forms part of the penetrator. Penetrators include bulkhead mounted connector assembly components.

Note 2 to entry: "Bushing" is an alternative commonly used term.

3.1.15
pressure integrity seal
sealing element of a penetrator assembly that prevents leakage between the two sides of the wall/partition to which the penetrator is mounted

3.1.16
primary pressure integrity seal
pressure integrity seal closest to the side with the highest rated absolute pressure (RAP)

Note 1 to entry: If only one value for RAP is specified (pressure balanced conditions), the primary pressure integrity seal is the seal closest to the side with the most aggressive/conductive medium.

Note 2 to entry: This definition applies to penetrators only.

3.1.17
rapid gas decompression
extreme depressurisation event from high pressure (hundreds of bar) to low pressure (tens of bars down to atmospheric) in order of seconds

Note 1 to entry: Rapid gas decompression can occur in a production system when in presence of gas. The phenomenon is also known as "explosive decompression".

3.1.18
rated absolute pressure
maximum absolute pressure that a connector assembly has been designed to operate at under the specified conditions of use

Note 1 to entry: For connector assemblies that are designed to operate under pressure balanced conditions, only one value of rated absolute pressure shall be specified. For penetrators that are designed to operate with different pressures on either side of a wall or partition, two values of rated absolute pressure shall be specified. RAP-1 shall be used to refer to the maximum rated absolute pressure on the external or outboard side of the partition and RAP-2 shall be used to refer to the maximum rated absolute pressure on the internal or inboard side of the partition.

Note 2 to entry: The rated absolute pressure shall not be confused with the maximum test pressure to which the assembly shall be subjected in order to qualify it for service.

3.1.19
rated differential pressure
maximum differential pressure that a connector assembly has been designed to operate at under the specified conditions of use

Note 1 to entry: For connectors and penetrators that are designed to operate under pressure balanced conditions, only one value of rated differential pressure shall be specified and shall be the same in both directions. For penetrators that are designed to operate with different pressures on either side of a wall or partition, the two values RAP-1 and RAP-2 shall be the rated differential pressure in each direction

Note 2 to entry: The rated differential pressure value shall be used to describe the differential pressure rating of the connector assembly and it should not be confused with the maximum differential test pressure to which the assembly shall be subjected in order to qualify it for service.

3.1.20
rated current
I_r
maximum RMS value of current which the connector assembly can carry continuously at rated frequency and at maximum ambient temperature, as given by the temperature class

Note 1 to entry: For connector assemblies operating at other environmental conditions, the rated current and corresponding operational ambient conditions shall be clearly specified in the data sheet. For penetrators and bulkhead mounted connectors, rated current may be given by operational conditions in the tank/housing to which it is mounted; these conditions shall be clearly specified in the data sheet.

3.1.21
rated thermal short-time current
I_{th}
RMS value of a symmetrical current which the connector assembly withstands thermally for the rated duration (t_{th}) immediately following continuous operation at rated current and frequency, with maximum temperatures of ambient sea water/operational media, as given by the temperature class

3.1.22
rated dynamic current
I_{d}
peak value of a current that the connector assembly withstands mechanically

3.1.23
routine test
tests performed by the manufacturer on each connector assembly to verify that the specified requirements are met

3.1.24
sample test
tests performed by the manufacturer on samples of connector assemblies or components taken from a connector assembly, at a specified sampling frequency, so as to verify that the finished product meets the specified requirements

3.1.25
secondary pressure integrity seal
pressure integrity seal closest to the side with the lowest rated absolute pressure (RAP)

Note 1 to entry: If only one value for RAP is specified (pressure balanced conditions), the secondary pressure integrity seal is the seal closest to the side with the less aggressive/conductive medium.

Note 2 to entry: This definition applies to penetrators only.

3.1.26
shell continuity
electrical connection between two metallic connector housings when connected together

3.1.27
special test
test other than a routine, sample or type test, agreed between manufacturer and purchaser

3.1.28
subsea protection cap
device connected to a connector half for protection when unmated subsea

Note 1 to entry: The subsea protection cap provides mechanical protection and prevents marine growth on critical/sealing surfaces.

3.1.29
temperature rise
difference between the temperature of the part under consideration and a reference temperature

[SOURCE: IEC 60050-151:2001, 151-16-26, modified – The note to entry has been deleted.]

3.1.30
test connector
connector used during topside testing, in order to test equipment and systems – without using the full delivery connector set

3.1.31
type test
conformity test made on one or more items representative of the production, in order to demonstrate satisfactory performance characteristics to meet the intended application

Note 1 to entry: Type tests are performed on connector assemblies representative of other connector assemblies, to demonstrate that these connector assemblies comply with the specified requirements.

Note 2 to entry: A connector assembly is considered to be representative of others if it is built to the same drawings using the same techniques in the same factory.

3.1.32
verification test
test conducted during the type test sequence to verify that the product is performing correctly and within the product performance specification

3.1.33
water seal
sealing element of a connector assembly that prevents intrusion of conductive media into the connector assembly internal volume

3.1.34
wet mateable connector
connector designed to be submerged in sea water, which can be connected/disconnected in a submerged condition – with no voltage or current applied

3.2 Abbreviated terms

CP	cathodic protection
CR	contact resistance
FAT	factory acceptance test
FEA	finite element analysis
IR	insulation resistance
MBR	minimum bend radius
PD	partial discharge
PMI	positive material identification
PSL	product specification level
RAP	rated absolute pressure
RDP	rated differential pressure
RGD	rapid gas decompression
ROT	remotely operated tool
ROV	remotely operated vehicle
U_0	rated power frequency voltage between a conductor and earth or metallic screen for which the connector assembly is designed
U	rated power frequency voltage between conductors for which the connector assembly is designed
U_m	maximum value of the "highest system voltage" for which the connector assembly may be used
UV	ultraviolet

4 Documentation and marking

4.1 Design documentation

Design documentation shall be provided and shall at least contain information as shown in Table 1. Some parts of the reports may contain confidential and proprietary information – such information shall as a minimum be made available for review, if not provided as part of the final documentation to the purchaser.

Table 1 – Design documentation

Preferred document	Document content
Design specification	Including design specification data sheet, operations interface specification, environmental, mechanical, electrical and thermal design specifications and cathodic protection requirements. Intended installation and intervention procedures.
Design drawings	Detailed, scaled mechanical drawings including weights, dimensions, cross sections and material/parts lists.
Materials specification	Materials selection report including material list and properties. Compatibility details, test procedures and report.
Design analysis report	Report containing mechanical, electrical and materials calculations and theoretical studies.
Assembly procedures	List of assembly procedures (including revision) used during type testing.
Cleaning and spillage requirements	Procedure with regards to cleaning and spillage requirements.
Handling, transport and storage	Document containing intended handling, transport and storage procedures. List of all fluids used in the product, including safety data sheets.

4.2 Type test documentation

A detailed test specification for each type test sequence is required. This specification shall include procedures, instruments, connection diagrams and all relevant environmental, mechanical and electrical parameters used and shall form the basis of communicating agreement between the client and the manufacturer in instances where deviations to this procedure are permitted. In addition, a type test report shall be provided demonstrating the outcome of each test within each sequence.

4.3 Routine test documentation

Routine test documentation shall be supplied as listed in Table 2.

Table 2 – Routine test documentation

Document	Document content
Routine test procedure	A detailed test specification for each routine test, embracing complete test procedures with all relevant environmental, mechanical and electrical parameters, instruments and connection diagrams used.
Routine test report	A test report shall be provided demonstrating the outcome of each test within the test sequence. The test report shall be compiled in a format as recommended by 4.2.

4.4 As built documentation

Further to successful type testing, each connector assembly shall be supplied with detailed as built documentation. Documents as listed in Table 3 shall be supplied, as a minimum, and shall contain information as shown in Table 3. Some parts of the reports may contain confidential and proprietary information – such information shall as a minimum be made available for review, if not provided as part of the final documentation to the purchaser.

Table 3 – As built documentation

Preferred document	Document content
Design report	Including design data sheet, design specification, operations interface specification, mechanical, electrical and thermal design analyses, routine test procedures, routine test results and cathodic protection influence report.
Design drawings	Detailed, scaled mechanical drawings including weights, dimensions, cross sections and material and parts lists.
Materials specification	Materials selection list and properties. Compatibility detail, test procedures and report.
Operation and maintenance manual	Installation, operation, intervention and maintenance information. Subsea water-jet and subsea citric acid and brush cleaning detailed procedures.
Traceability report	Individual component and materials traceability.
Handling and storage report	Handling, shipping, storage and preservation requirements.

4.5 Design analysis

The connector assemblies shall be subject to a design analysis on the critical areas of the design to verify that the design is capable of withstanding the stresses to which it may be subjected at all stages of its life. The design analysis shall as a minimum contain the following.

- The connector assembly design shall be subject to a design failure mode effect and criticality analysis (DFMECA) and the results documented. The output from the analysis shall be used to identify areas of interest for further analysis, testing and quality controls. It may be necessary to augment the testing programme given in this document in order to evaluate features of the design that have been identified by the DFMECA.
- Electrostatic, magnetic, thermal and mechanical finite element analysis, covering type tests and intended operational conditions shall be undertaken to evaluate the performance of the design where the performance cannot be inferred from other analysis. Consideration shall be given to worst-case design loads (e.g. test, storage, handling, installation/retrieval and operation) including fault scenarios (e.g. broken seal, short circuit) such that the design loads do not exceed electrical, thermal or mechanical limitations for any material. The analysis shall include the heat generated by the losses in the connector assembly itself. The analysis should also include possible nonlinear material properties.
- Calculations to verify suitability of the pressure compensating system shall be undertaken. The analysis shall include test, storage, transportation, installation/retrieval and operational conditions. Any hysteresis (lag) in the performance of the compensation system shall be included.
- The material properties and limitations used in the analysis shall be identified and documented based on qualified, recognised and repeatable fabrication processes. This is also applicable for bonding between materials.

4.6 Data sheet

A data sheet shall be created for each connector assembly. As a minimum, characteristic data for the connector assembly shall be documented in the format given in Annex A.

4.7 Equipment marking

4.7.1 Connectors and penetrators

The connector and/or penetrators shall be legibly and durably marked in a visible place with the following:

- name, logo or registered mark of the manufacturer or supplier;
- model/serial number;
- rated voltage, U_0/U (U_m);
- rated current, I_r;
- temperature class;
- rated frequency;
- rated absolute pressure, RAP (RAP-1 and RAP-2 for penetrators);
- rated differential pressure (penetrators only);
- water depth.

If space constraints limit the information that can be included on the product, the name/logo of manufacturer and model/serial number shall as a minimum be included.

4.7.2 Jumper assemblies

The jumper assemblies shall be legibly and durably marked on the outer surface at each end with the following information as a minimum:

a) name, logo or registered mark of the manufacturer or supplier;
b) model/serial number;
c) rated voltage, U_0/U (U_m);
d) rated current I_r;
e) rated frequency
f) type of cable insulation;
g) number and size of conductor;
h) absolute design pressure;
i) water depth;
j) temperature class;

If space constraints limit the information that can be included on the product, the name/logo of manufacturer and model/serial number shall as a minimum be included.

5 Design

5.1 General design requirements

The following design requirements shall apply to all types of connector assemblies:

a) service life time of 30 years;
b) maintenance free throughout service life;
c) minimum 50 surface recoveries;
d) minimum of two years storage onshore as part of the design service life.

5.2 Temperature class

This document establishes four main temperature classes of connector assemblies, as shown in Table 4. The temperature classes differentiate on the temperature in the media surrounding the connector assembly, not taking into account the heat generated by the connector assembly itself.

The specific values stated in Table 4 for each connector class shall be used in the type testing process to qualify the connector assembly according to the special application requirements. For some of the test sequences, different steps are defined for the classes.

Table 4 – Temperature classes

Parameter	Class I	Class II	Class III	Class IV
Minimum ambient temperature [a]	−5 °C	−5 °C	−5 °C	−5 °C
Maximum ambient temperature [a]	20 °C	60 °C	121 °C	> 121 °C [b]
Handling and storage temperature	−25 °C to 60 °C	−25 °C to 60 °C	−25 °C to 60 °C	−25 °C to 60 °C

[a] The specified ambient temperatures do not take into account the heat generated by the connector assembly itself.

[b] Maximum ambient temperature shall be specified in the data sheet.

5.3 Electrical design requirements

5.3.1 Ratings

5.3.1.1 Voltage ratings

The values of rated voltage for connector assemblies shall be according to Table 5.

Table 5 – Voltage ratings

U_0/U (U_m)	Rated voltage kV					
U_0/U	1,8/3	3,6/6	6/10	8,7/15	12/20	18/30
U_m	3,6	7,2	12	17,5	24	36

NOTE 1 The values in Table 5 are taken from IEC 60038:2009.

For systems with a rated "maximum" voltage, U_m, of 36 kV, the standard voltage ratings (i.e. U_0/U (U_m)) shown in Table 5 apply on systems with a nominal operating phase-to-phase voltage of 33 kV as well as 30 kV. The same U_0 of 18 kV shall be selected as the basis for establishing the test voltages referenced in the testing section (Clause 7 to Clause 14) for both systems with a nominal operating phase-to-phase voltage of 33 kV as well as 30 kV. No special labelling and/or marking is required to denote the higher phase-to-phase operating voltage of 33 kV.

NOTE Refer to IEC 60183:2015.

5.3.1.2 Current ratings

The rated current I_r of connector assemblies shall be in accordance with Table 6.

NOTE 1 The values of Table 6 are taken from IEC 60059.

Table 6 – Current ratings

Rated current A												
100	200	250	315	400	500	630	800	1 000	1 250	1 600	2 000	2 500

Rated current shall normally be specified for rated frequency in sea water at 20 °C for class I and in the relevant medium at the maximum ambient temperature as specified in Table 4 for classes II to IV. For connector assemblies operating in other conditions, the rated current and corresponding operational ambient conditions shall be clearly specified in the data sheet.

If the extended temperature rise test is performed, the current carrying capacity versus ambient temperature characteristics shall be included in the datasheet.

For systems involving harmonic currents, the system designer should select a current rating that considers the additional heat generated by the harmonic currents (both in the main conductor and cable screens as applicable). If considered required, and agreed between manufacturer and purchaser, additional temperature rise tests can be performed.

5.3.1.3 Short circuit current rating

Unless otherwise specified, the standard value of the rated thermal short-time current (I_{th}) shall be 25 times the rated current (I_r), t_{th} being 1 s.

Unless otherwise specified, the standard value of the rated dynamic current, I_d, shall have amplitude of the first peak equal to 2,5 times I_{th}.

The maximum permissible short circuit temperature of the conductors shall be calculated in accordance with IEC 60986 and/or be verified by the FEA.

5.3.2 Earthing

5.3.2.1 Earthing of cable screens

Connector assemblies shall have means for the earthing of housings and cable screens. The earthing connection shall be copper or a copper alloy, with a cross section area and current rating capacity similar to that of the cable screen; however, the cross-section area shall be a minimum of 6 mm^2.

For single phase jumpers (cables), screen currents could be considerable if the screens are earthed in both ends. If single-ended earthing of the screen is selected, the screen termination shall be designed to handle the induced voltage on the screen.

5.3.2.2 Shell continuity

Unless specified differently in the project requirements specification or data sheet, connectors shall be designed to provide a shell continuity corresponding to 100 mV voltage drop or less at room temperature (20 °C) with a current of 10 A DC.

5.3.3 Dummy connectors

Electrical voltage rating, including acceptable voltage test level, shall be clearly specified in the data sheet, and marked on each item.

5.4 Mechanical design requirements

5.4.1 Pressure classes

Pressure retaining components (penetrators, bushings, bulkhead mounted connectors, etc.) shall be categorized and qualified to standardised rated absolute pressure classes (RAP, RAP-1, RAP-2), in accordance with API Spec 6A as shown in Table 7.

Table 7 – Pressure classes

Pressure classes according to API Spec 6A							
Pressure (bar)	138	207	345	690	1 035	1 380	1 861

5.4.2 Rapid gas decompression

Connector assemblies or parts of connector assemblies that will be in contact with production fluids shall be tested for rapid gas decompression. Allowable operational changes in pressures and tolerance to rapid gas decompression (RGD) shall be documented where applicable. Tolerance to RGD shall be stated in the data sheet.

5.4.3 External forces

Rotational forces, vibrations, tensions, compressions shall not impair the function or quality of the connector assembly, throughout design service life.

A retaining mechanism for securing sheaths, screens and armour shall be incorporated in the connector assembly design, in order to verify mechanical and electrical suitability.

The connector assembly shall have an impact protection rating, IK10, according to IEC 62262.

5.5 Material requirements

5.5.1 General material requirements

The connector assemblies shall meet the following requirements.

a) The connector assembly shall comprise proven materials and components, which are qualified and suitable for relevant equipment, applications and environments, and the design life. The connector assembly shall be compatible throughout design service life with the relevant interfacing medium and materials as defined in the operational requirements specification.

b) Seal materials shall be compatible with all applicable interfacing materials and media, even if one seal should fail.

c) All polymeric materials shall be compatible with the service environment.

d) The connector assembly shall be designed to be cathodically protected or made of a sea water resistant material. Due consideration shall be given to chosen materials and system design; to ensure correct material protection in order to reduce the possibility of corrosion, calcareous build-up and hydrogen embrittlement.

e) A materials selection report including type test reports shall be prepared and presented to the purchaser, before construction of connector assemblies for type testing.

Consequence of potential migration or ingress of conductive media into the connector assembly shall be considered during the design phase, also considering densities of internal fluid compared with the external conductive media (and where conductive media may accumulate).

5.5.2 Material certification requirements

All connector and penetrator assemblies shall have traceable manufacturing records to allow identification and subsequent rectification of defects after delivery. Manufacturing records and test results shall be traceable to each assembly by a unique identifier (e.g. product serial number). Traceability of components from a common batch is permitted.

For well pressure retaining equipment, the traceability requirements for individual components used in the assembly shall be according to the latest edition of API Spec 6A for the required PSL level of the component in question. Where the component PSL level requires traceability to a specific heat treatment lot, a unique means of identification of the component to the heat run shall be provided.

The composition of all metallic components used for process (well) containment shall be verified by PMI according to the manufacturer's procedure. The PMI shall be performed as late as possible in the assembly process and the result documented.

Certificates of conformity for metallic components shall be supplied with the product according to Type 3.1 of EN 10204. Records shall be retained by the manufacturer for a minimum of 10 years.

5.6 Connector specific requirements

5.6.1 General requirements

The following requirements shall apply to all types of connectors.

a) Efforts shall be made to maximize the duration which a connector half can remain unmated in the operational environment. Minimum product requirement is 28 days over the lifetime, with a minimum of 7 consecutive days.

b) Physical contact between electrical contacts of opposing connector assembly halves during primary engagement of the connector assembly shall not be possible. This is to prevent damage due to exposure to primary alignment forces.

Connector assemblies shall be designed:

c) to be capable of vertical, tilted and horizontal operation inclusive of mating and de-mating, or as specified in the datasheet,

d) with a robust locking mechanism, to prevent accidental or vibration-induced de-mating or malfunction, and

e) to have a housing and latch mechanism tolerant to silt and fine sand deposits.

5.6.2 Wet mateable connectors

The following are additional requirements for wet mateable connectors.

a) Wet mateable connectors shall be designed for a minimum of 100 maintenance free mate/de-mate cycles, after delivery.

b) Wet mateable connectors shall be designed to withstand calcium deposits, marine growth and debris without jamming, and without interfering with mating, de-mating and operation.

c) Wet mateable connectors shall be designed for operation within the presence of sand and silt, and tolerant to silt and fine sand deposits (e.g. mating areas, housing and locking mechanism). The connector assembly design shall not be susceptible to damage by sand particles during mating or de-mating.

d) The connector assembly shall be designed for water-jet cleaning of marine growth in the mated condition, or with a dummy connector/protection cap installed. The potential risks of performing this water jetting shall be clearly defined and documented in the operation and maintenance manual.

e) The connector assembly shall be designed for acid cleaning with citric acid and brushed with a purpose made ROV brushing tool to remove calcium growth. All applicable limitations shall be clearly defined and documented in the operation and maintenance manual, for example maximum concentrations and durations when using citric acid.

f) The connector assembly shall be designed with clearly visible indications of correct rotational and axial alignment prior to and during mating. The connector assembly shall also have self-evident means to indicate that the connector assembly is fully mated, i.e. a positive fully mated indication shall be part of the design. Visual indication shall be clearly visible from a ROV camera. This requirement does not exclude the use of stab type connectors mounted into a separate mating/locking mechanism.

5.6.3 Dry mateable connectors

The following are additional requirements for dry mateable connectors.

a) Dry mateable connectors shall be designed for a minimum of 30 maintenance free mate/de-mate cycles, after delivery.

b) Dry mateable connectors shall be suitable for mating/de-mating in harsh offshore conditions, for example in a humid and salt atmosphere.

c) Means for testing seals between the connector halves after mating should be considered.

5.7 Penetrator specific requirements

5.7.1 Penetrators for pressure compensated equipment

Penetrators used as equipment penetrations for pressure compensated housings shall be designed for normal loading conditions under testing, deployment and usage. If a system requires fault tolerance under abnormal loading conditions including fault scenarios (e.g. internal fault or failure of the compensation system) or if the compensation system has a nominal over-pressure of greater than 10 bar, the system designer should specify the use of a penetrator for pressure retaining equipment (5.7.2). Penetrators for pressure compensated equipment shall be designed with a nominal rated differential pressure of 10 bar (in both directions) at the specified temperature range to allow for pressure differences that may occur between the two compensated volumes due to compensator response lag, temperature differences, etc.

NOTE The rated differential pressure of 10 bar is applicable to the penetrator as a component, and not necessarily to the tank/housing it is attached to.

5.7.2 Penetrators for pressure retaining equipment

The following requirements are required for penetrators which are exposed to differential pressure above what is normally seen for pressure compensated assemblies.

Pressure retaining penetrators shall be designed to operate at the rated absolute pressure applied as differential pressure across the penetrator (RAP-1 and RAP-2).

Components intended for differential pressure service shall be designed and tested mechanically (in addition to tests specified in this document) according to the design code applicable for the equipment to which it is mounted. If not specified, API Spec 6A should be used as a reference, where PSL 3 and PR2 shall be the level of technical qualification and documentation.

The applicable temperature range shall be clearly specified and related to the pressure rating requirements.

For pressure integrity seals, see 5.8.3.

Whilst this document deals with the requirements for the product only, it is important to recognise that the failure of a penetrator in a pressure retaining application could result in consequences for the system on which it is used. These consequences should be identified at the system design stage so that mitigating actions can be taken.

5.8 Seals

5.8.1 General seal requirements

The use of test ports for testing of seals shall be minimized. Where test ports are introduced, careful consideration shall be made in order not to introduce new potential leakage paths and reduce the main seals integrity level. Where two seals are installed, these shall be installed on different seal surfaces. Each seal shall be tested during type testing; at least one seal shall be tested during factory acceptance test.

Each seal shall be designed and qualified for continuous exposure to the relevant media (sea water, oil, water/glycol etc.) at the rated absolute pressure and temperature. Failure of one of the seals shall not jeopardise the function or integrity of the remaining seal. The connector assembly shall operate within its specified electrical requirements with only one seal in operation.

Manufacturer shall identify all seals and classify whether they are water seals, pressure integrity seals or provide both functions (combined).

5.8.2 Water seals

In general, all connector assemblies shall incorporate a minimum of two water seals between the conductive media and the electrical conductors/live parts.

The sealing components of the connector assembly shall not deform the cable insulation or the outer semi-conductive layer in such a way as to lower the electric or mechanical strength of the cable.

The principle with two water seals is also applicable to dummy connectors (main connector disconnected).

5.8.3 Additional requirements for pressure integrity seals

5.8.3.1 Exposed to production fluids

Seals that are exposed or may be exposed to production fluids shall be qualified to PSL 3 or PSL 3G and PR2 as per API Spec 6A. The connector assembly shall have at least two independent pressure integrity seals, unless an API 6A BX seal (or proven industry equivalent) is utilized. Each of the seals shall be installed on different seal surfaces.

Subclause 5.8.3.1 also applies to seals for penetrators for pressure compensated equipment.

5.8.3.2 Not exposed to production fluids

For connector assemblies for pressure compensated equipment that are not and may not be exposed to production fluids, one or two pressure integrity seals may be used.

5.9 Electric field control

Electric field control shall be applied as part of the cable termination when the cable has an outer semi-conductive insulation layer.

5.10 Jumper assemblies

Jumper assemblies shall be flexible. Details on minimum bending radius and the force required to achieve this shall be specified in the data sheet.

Cable jumpers or fluid-filled hose jumpers may be used. Where fluid-filled jumpers are employed, these shall be pressure balanced and volume compensated for the specified environmental conditions (Table 4).

For fluid-filled jumper assemblies, the required pre-charge pressure and volume shall be determined by design calculation and limits for their values shall be set for use in assembly and in subsequent verification testing for both routine and type testing. A positive overpressure shall be maintained in all deployed conditions.

Jumper assemblies shall have a tension strength element included to avoid tensional forces (caused by e.g. snagging and/or weight of connector assemblies) in the cables.

Electrical cables shall be electrically routine tested in accordance with ICEA S-93-639, ICEA S-96-659 and their referenced sections of ANSI/ICEA T-27-581. Cable category (100 %, 133 %, 173 %) shall be stated in the data sheet.

NOTE The requirement to use cables tested to ICEA standards does not preclude the use of cables that have been manufactured to international standards other than ICEA. It merely requires that such cables are electrically routine tested to the requirements of ICEA.

5.11 Storage and transportation

Storage and transportation shall be considered during the design of the connector assembly. Special consideration shall be given to shock and vibration, pre-pressurised equipment, minimum bending radius of electrical jumpers and protection of those parts easily susceptible to damage. Onshore protection caps shall be provided. Handling, storage and transportation requirements shall be documented (Table 1).

6 Tests

6.1 Structure of test clauses

The testing of connector assemblies and their component parts according to this document is divided in to type tests, routine tests, sample tests and special tests. Generally, Clause 7 to Clause 13 specify the tests to be performed and in which sequence, while Clause 14 comprises detailed test procedures for the specified tests (except for Clause 12 which comprises both test sequence and procedures). The type test sequence in Clause 11 has been designed to capture cumulative ageing effects.

Annex B includes some figures that have been included to support some of the penetrator test sequences. These figures are for information only and may deviate from actual penetrator design and test set-up.

6.2 General test requirements

Detailed test procedures with unambiguous test setup sketches shall be developed based on this document.

Each item undergoing a type or routine test shall be visually examined to ensure that no evidence of damage exists prior to testing and to provide a visual indication of a sound working assembly. Visual inspection shall be repeated after testing is completed. Both the pre and post testing visual examinations shall be recorded within the test documentation.

Each mate/de-mate and lock/unlock process shall be undertaken as described within the relevant test procedure, and the details tabulated and logged.

The hyperbaric test set-up shall allow electrical testing at the specified test pressure.

Unless otherwise specified, the rate of pressure change shall be a minimum of 20 bar/min.

The results of the following tests shall be recorded and graphed each time they are undertaken during the type testing sequences in order to highlight trends:

a) contact resistance test;
b) insulation resistance test;
c) partial discharge test (PD inception voltage as applicable).

These data shall then be used to identify and control variances in the performance of the product and to drive continuous improvement.

Where applicable, effects resulting from temperature differences during the course of taking these readings shall be accounted for.

Where applicable, it shall be possible to de-mate/mate, lock/unlock wet-mate connector assemblies while submerged and under pressure.

During the test programme, connector assemblies shall be fitted with a sample of the cable that is intended to be used in service.

In the case that RAP-2 = 1 atm, the tests specified with RAP-2 as the test pressure are not applicable.

6.3 Artificial sea water

For tests performed in artificial sea water, the following requirements shall be met.

a) Artificial sea water for material testing shall be manufactured according to ASTM D1141-98.
b) For type testing, water shall be used with a salinity of 35 000 ppm[1] ± 5 % (produced using common salt plus mains water) containing 1,5 % ± 0,15 % by weight sand and silt. The particle size distribution shall be according to ISO 12103-1, A.4 coarse test dust standard grade. The water shall be continuously agitated while performing the tests to ensure that solids remain in suspension and are evenly distributed.
c) The composition and temperature of the sea water shall be established, recorded and verified prior to testing.

6.4 Test media

Whenever practically possible, the environmental fluid the connector assembly will be exposed to during operations shall be used as test media. When unpractical, purchaser and manufacturer shall agree on suitable test media. Table 8 indicates possible test media for type and/or routine tests. The actual fluid used shall be documented in the test report.

1 ppm = part per million

Table 8 – Test media

		Type tests							Routine tests			RGD
	Allowed test media in addition to actual operational fluid	Water		MEG-water mixture or other conductive Fluid	Insulating Dielectric fluid	Nitrogen or inert gas	Production Fluids	Production Fluids gas	Tap water	Insulating Dielectric Fluid	Gas (typically nitrogen)	
Operating fluid	Typical use	Artificial sea water per 6.3	Tap water				Per Table F.2 of API Spec 6A:2018, F.1.13.5.2					ISO 23936-2:2011, Clause 7, shall apply per NORSOK M-710:2014, section 7
Sea water	Subsea	R	A[a]				A[d]		R			
MEG-water mixture or similar	Motors	A[d]	A[a]	R			A[d]		R			
Insulating dielectric fluid[e]	Motors, transformers, VSD, SWGs	A[d]	A[a]	A[d]	R[c]		A[d]		A[d]	R		
Air, nitrogen or other inert gas	VSD, SWGs, control modules					R			A[d]		R	
Production fluids	In-well applications	A	A[a]	A			R		R			A
Production fluids – gas content > 30 %	Gas cooled motors	A[bd]	A[bd]			A[b]		R			R	A
Other insulating fluids or solids	Gel- or resin filled equipment	A[d]	A[a]	A[d]	R				A[d]	R		

Key

R: recommended

A: alternative

[a] Tap water can be used for tests not involving mate/de-mate operations; otherwise artificial sea water shall be used.

[b] Allowed when safety (explosion) is a concern for long term test.

[c] Except for inner water seal test, where test media shall be conductive.

[d] Test medias accepted as alternative are done on the basis they provide a more stringent test regime. This is done to provide flexibility in the way test procedures and test set-ups are defined, and to allow potential test sequence simplification and reduced test execution.

[e] Insulating dielectric fluid is assumed to be either a fluid which is continuously renewed, or which is enclosed in such a way that degradation of the fluid does not compromise its insulating capabilities over the lifetime of the equipment. If the media is expected to be contaminated or polluted during normal use, other conductive fluid media shall be used.

7 Routine tests – Connectors and penetrators

Routine tests for connectors and penetrators shall be performed in accordance with Table 10. Electrical tests as specified in Table 9 shall be performed where "electrical tests" are specified in the test sequence.

Table 9 – Electrical routine tests

Test	Reference
Contact resistance	14.2
Insulation resistance	14.8
Shell continuity test [a]	14.3
Screen continuity test	14.4

[a] Applicable to connector assemblies that provide continuity between the bodies of the mating connector halves.

The acceptance criteria for each of the tests are defined in the references in Table 9 and Table 10.

Table 10 – Routine test sequence – Connectors and penetrators

Step	Test	Test level	Connectors	Penetrators	Reference
1	Helium leak test	See test method	X	X	14.1
2	Electrical tests	See test methods	X	X	Table 9
3	PD test	1,73·U_0 (10 pC)	X	X	14.5
4	Mate/de-mate Connectors only	1 operation in air – no misalignment	X		N/A
5	Electrical tests	See test methods	X		Table 9
6	Submerse in environmental media	Soak for 15 min	X		N/A
7	Electrical tests	See test methods	X		Table 9
8	Pressurise	To 1,1·RAP Hold time 20 min	X		
9	Electrical tests	See test methods	X		Table 9
10	De-mate/mate Wet mate connectors only	1 operation at 1,1·RAP	X		
11	Depressurise	To atmospheric pressure Hold time 15 min	X		N/A
12	De-mate/mate Connectors only		X		
13	Electrical tests	See test methods	X		Table 9
14	Static pressure test Penetrators only	See test method – direction 1 and 2		X	14.16
15	Electrical tests	See test method	X	X	Table 9
16	PD test	1,73·U_0 (10 pC)	X	X	14.5
17	PD test	2,5·U_0 (200 pC)	X	X	14.5
18	High voltage AC test	2,5·U_0 (30 min)	X	X	14.6

Step	Test	Test level	Connectors	Penetrators	Reference
19	PD test	1,73·U_0 (10 pC)	X	X	14.5
20	PD test	2,5·U_0 (200 pC)	X	X	14.5

8 Routine tests – Dummy and test connectors

Dummy and test connectors shall be subject to the same routine tests as connectors and penetrators that are referenced in Table 10 wherever practically possible and relevant to do so.

Where it is not practical to perform a test in the sequence due to the function of the dummy or test connector, that particular test may be omitted.

EXAMPLE 1 Omitting pressure tests on a test connector intended only for topside use.

EXAMPLE 2 Omitting the insulation test between each contact and earth on a connector fitted with low voltage resistors to verify line continuity between phases.

If additional tests are required to evaluate a function of a test connector, that could not be evaluated by the tests given in Table 10; these deviations shall be explained and justified by the manufacturer.

9 Routine tests – Jumper assemblies

The test sequence specified in Clause 9 is applicable to complete connector assemblies, including jumper assemblies. Individual component testing on each connector/penetrator shall be completed in accordance with Clause 7 prior to this test sequence. For hoses and hose terminations, sample testing in accordance with Clause 10 is also required.

Where fluid-filled hose jumpers are used, the assembly shall be immersed in tap water and leak tested with helium or nitrogen to the specified design pre-charge pressure for a minimum period of 2 h. There shall be no leaks as evidenced by pressure drop below the design limit and by gas escaping from the assembly. The jumper pre-charge pressure shall be recorded before the hyperbaric testing.

Electrical tests as specified in Table 9 shall be performed where "electrical tests" are specified in the test sequence.

The acceptance criteria for each of the tests are defined in the references in Table 11.

Table 11 – Routine test sequence – Complete jumper assemblies

Step	Test	Test level	Reference
1	Electrical tests at atmospheric pressure, dry	See test methods	Table 9
2	PD test at atmospheric pressure, dry	1,73·U_0 (10 pC)	14.5
3	Submerge connector assembly and allow to soak for 15 min		
4	Increase pressure from atmospheric to 0,3·RAP Hold pressure for 10 min		
5	Decrease pressure to atmospheric pressure Wait 10 min before next pressure cycle		
6	Increase pressure from atmospheric to 0,7·RAP Hold pressure for 10 min		

Step	Test	Test level	Reference
7	Decrease pressure to atmospheric pressure Wait 10 min before next pressure cycle		
8	Increase pressure from atmospheric to 1,1·RAP Hold pressure for 15 min		
9	Electrical tests at 1,1·RAP	See test methods	Table 9
10	Decrease pressure to atmospheric pressure Wait 15 min		
11	Electrical tests at atmospheric pressure	See test methods	Table 9
12	PD test at atmospheric pressure	1,73· U_0 (10 pC)	14.5
13	PD test at atmospheric pressure	2,5· U_0 (200 pC)	14.5
14	High voltage AC test	2,5· U_0 (30 min)	14.6
15	PD test at atmospheric pressure	1,73·U_0 (10 pC)	14.5
16	PD test at atmospheric pressure	2,5· U_0 (200 pC)	14.5

10 Sample tests – Hoses

For applications including jumpers with fluid-filled hoses, sample tests shall be performed on the hoses. The tests that shall be performed are specified in Table 31 (only two tests applicable to sample testing). A minimum of one sample per batch shall be tested.

11 Type and special tests – Connectors and penetrators

11.1 Order of tests and type test requirements

The following requirements apply for type tests.

a) Most of the specified type tests are mandatory and shall be performed on the same connector assembly without refurbishment. The sequence shall be performed as given in Table 12 and this sequence takes precedence over the order in which the tests appear in the text of this document. The tests included in this sequence constitute the base sequence and are labelled B (base sequence) in Table 12.

b) Some of the mandatory tests may be performed on separate connector assemblies, as individual tests, and in an order as agreed between the manufacturer and purchaser. These tests are not considered critical for the cumulative stress effect achieved during the base sequence in 11.1 a). These tests are labelled P (parallel testing) in Table 12.

c) Special tests are subject to agreement between the purchaser and manufacturer and shall be specified in the test procedure. These tests are labelled S (special) in Table 12. When to perform these in the test sequence, and whether they shall be performed as part of the base sequence or as a parallel test, is subject to agreement between purchaser and manufacturer.

d) For penetrators, water seals and pressure integrity seals may be combined when the same seal provides both functions. In such cases, two or more of the water seal and pressure integrity seal tests (test no. 15 to 20 in Table 12) may be combined into one or more common tests.

Test 18 and test 20 in Table 12 are not required if secondary pressure integrity seals are removed during qualification of the penetrator per Table 12, step 7 and step 8 (as part of the base sequence).

Cable(s) shall be terminated to the connector assembly and compensating system installed (as applicable) during the type test program.

Testing may compromise the integrity of the component or part being tested and may be destructive. The assemblies tested shall not be used in operation.

The choice of test media shall be derived from Table 8. Manufacturers shall also verify that manufacture and assembly of all parts can be repeated with sufficient quality.

Table 12 – Type test sequence

Step	Test	Application			Test sequence reference
		Connectors	Penetrators Pressure-retaining	Penetrators for pressure balanced equipment	
0	Material testing	P	P	P	14.28
1	Prototype manufacturing acceptance test	B	B	B	11.4
2	Mate/de-mate operation test	B			14.24
3a	Electrical and thermal test – Connectors	B/P/S			11.5
3a-1	Temperature rise test	P			
3a-2	Extended temperature rise test – Connectors	S			
3a-3	Thermal cycles at atmospheric pressure – 15 cycles	B			
3a-4	Thermal cycles at RAP, 30 cycles (class I, II and III) / 60 cycles (class IV)	B			
3b	Electrical and thermal test – Penetrators		B/P/S	B/P/S	11.5
3b-1	Temperature rise test		P	P	
3b-2	Extended temperature rise test – Penetrators		S	S	
3b-3	Thermal cycles at atmospheric pressure – 15 cycles		B	B	
3b-4	Thermal cycles at RAP/RAP-1/RAP-2 30 cycles (class I, II and III) / 60 cycles (class IV)		B	B	
4a	Endurance test – Connectors	B			11.12
4b	Endurance test – Penetrators		B	B	11.13
5	Electrical short circuit test	P/S	P/S	P/S	11.6
5-1	Thermal short circuit test	P	P	P	
5-2	Dynamic short circuit test	S	S	S	
6	Hyperbaric test	B			11.7
7	Pressure cycling test – Penetrators		B	B	11.8
8	Combined pressure and temperature cycling test – Penetrators [a]		S/B		11.9
9	Extended static pressure test – Penetrators [a]		S/B		14.17
10	Rapid gas decompression test [a]	S/B	S/B		11.10
11	Mechanical and environmental stress tests	B/P/S	B/P/S	B/P/S	11.11
11-1	Thermal shock test	B	B	B	
11-2	Bending moment and free fall tests	P	P	P	
11-3	Shock and vibration test	P	P	P	

Step	Test	Application			Test sequence reference
		Connectors	Penetrators Pressure retaining	Penetrators for pressure balanced equipment	
11-4	Conductor pull test	P	P	P	
11-5	Cable pull test	P	P	P	
11-6	Cable termination bending test	S	S	S	
11-7	Cleaning and spillage test	P	P	P	
12	Impulse withstand voltage test	B	B	B	14.7
13	Inner water seal hyperbaric test – Connectors	B			11.14
14	Outer water seal hyperbaric test – Connectors	S			11.16
15	Inner water seal pressure cycling test – Penetrators		B	B	11.15
16	Outer water seal pressure cycling test – Penetrators		S	S	11.17
17	Secondary pressure integrity seal test – Penetrators		B	B	11.18
18	Primary pressure integrity seal test – Penetrators [a]		P	P	11.19
19	Secondary pressure integrity seal combined pressure and temperature cycling test – Penetrators [a]		P		11.20
20	Primary pressure integrity seal combined pressure and temperature cycling test – Penetrators [a]		P		11.21
21	Extended hyperbaric wet mate test	S			11.22
22	HV breakdown test	P	P	P	14.26
23	Dismantling and examination	B	B	B	14.25

B mandatory tests, performed in specified sequence.

P mandatory tests; can be performed in parallel on separate test specimen.

S special test, shall be performed if agreed between manufacturer and purchaser.

[a] These tests are mandatory for penetrators exposed to or potentially exposed to production fluid/gas.

CR, IR and PD tests at the start of a new test sequence are not necessary if already performed at the end of the previous sequence. If dismantling of a connector assembly has been performed, the tests of Table 13 shall be performed prior to starting the next test sequence.

Table 13 – Intermediate electrical tests

Step	Test	Test level (acceptance)	Reference
1	Contact resistance	See test method	14.2
2	Insulation resistance	See test method	14.8
3	PD test	$1{,}73 \cdot U_0$ (10 pC)	14.5
4	PD test	$2{,}50 \cdot U_0$ (200 pC)	14.5
5	High voltage AC test	$2.5 \cdot U_0$ (1 h)	14.6
6	PD test	$1{,}73 \cdot U_0$ (10 pC)	14.5
7	PD test	$2{,}5 \cdot U_0$ (200 pC)	14.5

11.2 Type tests – Dummy and test connectors

Dummy and test connectors that are to be used at operation voltage or higher, and/or be submerged, shall be subject to type tests in accordance with Table 12, unless it can be demonstrated that type tests already performed for the associated connector assembly also cover the dummy/test connector design. Where it is not practical to perform a test in the sequence due to the function of the dummy or test connector, that particular test may be omitted.

EXAMPLE 1 Omitting pressure tests on a test connector intended only for topside use.

EXAMPLE 2 Omitting the insulation test between each contact and earth on a connector fitted with low voltage resistors to verify line continuity between phases.

It may also be necessary to perform additional tests to evaluate a function of a test connector that is not evaluated by the tests given in Table 12. Whenever such deviations are required, these deviations shall be explained and justified by the manufacturer.

11.3 Type tests – New interface cable

Where a design has been previously type tested to this document but there has been a change to the cable interface to suit a new type of cable, some of the type tests shall be repeated. The tests listed in Table 14 shall as a minimum be repeated unless reasonable justification for not doing so is provided by the connector manufacturer. The steps given in Table 14 refer to those that are listed in Table 12 that shall be repeated. Only mandatory tests are listed; special tests may also be performed, subject to agreement between manufacturer and purchaser.

Table 14 – Type test sequence – New interface cable

Step [a]	Test	Test sequence reference	Comment
0	Material testing	14.28	Required if new materials are used
1	Prototype manufacturing acceptance test	11.4	It is not required to repeat static pressure test – penetrators
4a-1	Temperature rise test – Connectors	11.5	This test may be combined with step 3b-1
3a-3	Thermal cycles at atmospheric pressure – 15 cycles		
3a-4	Thermal cycles at RAP, 30 cycles (class I, II and III) / 60 cycles (class IV)		
3b-1	Temperature rise test – Penetrators	11.5	This test may be combined with step 3a-1
3b-3	Thermal cycles at atmospheric pressure – 15 cycles		
3b-4	Thermal cycles at RAP-1/RAP-2, 30 cycles (class I, II and III) / 60 cycles (class IV)		
5-1	Thermal short circuit test	11.6	
6	Hyperbaric test	11.7, steps 7, 15 to 19	This test may be combined with step 3b-4
11	Mechanical and environmental stress tests	11.11	
11-1	Thermal shock test		
11-2	Bending moment and free fall tests		
11-3	Shock and vibration test		
11-4	Conductor pull test		
11-5	Cable pull test		
11-6	Cleaning and spillage test		Material test to be considered

Step [a]	Test	Test sequence reference	Comment
13	Inner water seal hyperbaric test – Connectors	11.14	30 pressure cycles at 1,1·RAP (flooded conditions). Mate/de-mate operations are not required.
15	Inner water seal pressure cycling test – Penetrators	11.15	
22	HV breakdown test	14.26	
23	Dismantling and examination	14.25	

[a] Step refers to Table 12.

If there is a change in the cable manufacturer but the cable is manufactured to the same specification (dimensions, tolerances, materials, conductor cross section, conductor construction, voltage and current ratings, etc.), then type tests to be repeated may be limited to prototype manufacturing acceptance test (step 1 in Table 14) and inner water seal test (Table 14, step 13, for connectors and Table 14, step 15, for penetrators).

If the manufacturer can document that the thermal performance of the connector assembly with the new cable is equal to or better than with the original cable, it is not necessary to repeat the thermal tests (steps 4 and 5 in Table 13). Such exception shall be agreed between purchaser and manufacturer.

11.4 Prototype manufacturing acceptance test

11.4.1 Objective

This test is to highlight any manufacturing defects within the connector assembly and to ensure a healthy product at the start of the type test process.

11.4.2 Sequence

The test sequence shall be according to Table 15.

Table 15 – Prototype manufacturing acceptance test sequence

Step	Test	Test level	Reference
1	Helium leak test	See test method	14.1
2	Static pressure test – Penetrators	See test method – direction 1 and 2	14.16
3	Electrical tests	See test method	Table 9
4	PD test	1,73·U_0 (10 pC)	14.5
5	PD test	2,50·U_0 (200 pC)	14.5
6	High voltage AC test	4·U_0 (1 h)	14.6
7	PD test	1,73·U_0 (10 pC)	14.5
8	PD test	2,5·U_0 (200 pC)	14.5

11.4.3 Acceptance criteria

The acceptance criteria for each of the tests are defined in the references in Table 14.

11.5 Electrical and thermal tests

11.5.1 Objective

This test is to ensure that the connector assembly can effectively deal with load changes, both at and without hyperbaric pressure. Information about capability for operation in air shall also be determined.

11.5.2 Sequence

The type test sequence for connectors shall be according to Table 16.

Test sequences for penetrators shall be according to Table 17 and Table 18.

NOTE Since penetrators for pressure balanced equipment have the same RDP in both directions, the test sequence for these is simpler than that for pressure retaining penetrators.

Table 16 – Electrical and thermal test sequence – Connectors

Step	Test	Test level	Reference
1	Contact resistance	See test method	14.2
2	Insulation resistance	See test method	14.8
3	PD test	$1{,}73 \cdot U_0$ (10 pC)	14.5
4a	Temperature rise test	See test method	14.12
4b	Extended temperature rise test [a]	See test method	14.13
5	Thermal cycles	15 cycles at atmospheric pressure	14.14
6a	Thermal cycles – Class I, II and III [b]	30 cycles at 1,1·RAP	14.14
6b	Thermal cycles – Class IV [b]	60 cycles at 1,1·RAP	14.14
7	Contact resistance	See test method	14.2
8	Insulation resistance [c]	See test method	14.8
9	PD test [c]	$1{,}73 \cdot U_0$ (10 pC)	14.5
10	High voltage AC test [c]	$2{,}5 \cdot U_0$ (1 h)	14.6
11	PD test [c]	$1{,}73 \cdot U_0$ (10 pC)	14.5

[a] Special test – May be performed if agreed between manufacturer and purchaser.

[b] For this test, if agreed between manufacturer and purchaser, the RAP can be reduced to maximum operating pressure of the connector when under electrical load rather than the shut-in pressure under no load conditions.

[c] IR, PD and HV tests are not applicable when temperature sensors make this impossible.

Table 17 – Electrical and thermal test sequence – Pressure retaining penetrators

Step	Test	Test level	Reference
1	Contact resistance	See test method	14.2
2	Insulation resistance	See test method	14.8
3	PD test	$1{,}73 \cdot U_0$ (10 pC)	14.5
4a	Temperature rise test	See test method	14.12
4b	Extended temperature rise test [a]	See test method	14.13
5	Thermal cycles	15 cycles at atmospheric pressure	14.14
6a	Thermal cycles – Class I, II and III	30 cycles at 1,1·RAP-1 Pressure applied at outboard side	14.14

Step	Test	Test level	Reference
6b	Thermal cycles – Class IV	60 cycles at 1,1·RAP-1 Pressure applied at outboard side	14.14
7	Insulation resistance	See test method	14.8
8a	Thermal cycles – Class I, II and III [b]	30 cycles at 1,1·RAP-2 Pressure applied at inboard side	14.14
8b	Thermal cycles – Class IV [b]	60 cycles at 1,1·RAP-2 Pressure applied at inboard side	14.14
9	Contact resistance	See test method	14.2
10	Insulation resistance [c]	See test method	14.8
11	PD test [c]	1,73·U_0 (10 pC)	14.5
12	High voltage AC test [c]	2,50·U_0 (1 h)	14.6
13	PD test [c]	1,73·U_0 (10 pC)	14.5

[a] Special test – May be performed if agreed between manufacturer and purchaser.

[b] For this test, if agreed between manufacturer and purchaser, the RAP-2 can be reduced to maximum operating pressure of the penetrator when under electrical load rather than the shut-in pressure under no load conditions.

[c] IR, PD and HV tests are not applicable when temperature sensors make this impossible.

Table 18 – Electrical and thermal test sequence – Penetrators for pressure balanced equipment

Step	Test	Test level	Reference
1	Contact resistance	See test method	14.2
2	Insulation resistance	See test method	14.8
3	PD test	1,73·U_0 (10 pC)	14.5
4a	Temperature rise test	See test method	14.12
4b	Extended temperature rise test [a]	See test method	14.13
5	Thermal cycles	15 cycles at atmospheric pressure	14.14
6a	Thermal cycles – Class I, II and III	30 cycles at 1,1·RAP Pressured applied on both sides	14.14
6b	Thermal cycles – Class IV	60 cycles at 1,1·RAP Pressure applied on both sides	14.14
7	Contact resistance	See test method	14.2
8	Insulation resistance [b]	See test method	14.8
9	PD test [b]	1,73·U_0 (10 pC)	14.5
10	High voltage AC test [b]	2,50·U_0 (1 h)	14.6
11	PD test [b]	1,73·U_0 (10 pC)	14.5

[a] Special test – May be performed if agreed between manufacturer and purchaser.

[b] IR, PD and HV tests are not applicable when temperature sensors make this impossible.

11.5.3 Acceptance criteria

The electrical performance of the connector assembly shall remain within the specified test and design limits throughout the test sequence. The acceptance criteria for each of the tests are defined in the subclauses that are referenced in Table 16, Table 17 and Table 18.

11.6 Electrical short circuit test

11.6.1 Objective

This test sequence is to ensure that the connector assembly can withstand the maximum design short circuit current without any degradation or damage.

11.6.2 Sequence

The sequence of the electrical short circuit type test shall be according to Table 19.

Table 19 – Electrical short circuit test sequence

Step	Test	Test level	Reference
1	Contact resistance	See test method	14.2
2	Insulation resistance	See test method	14.8
3	PD test	1,73·U_0 (10 pC)	14.5
4	Thermal short circuit test	See test method	14.10
5	Dynamic short circuit test [a]	See test method	14.11
6	Contact resistance	See test method	14.2
7	PD test	1,73·U_0 (10 pC)	14.5
8	High Voltage AC test	2,50·U_0 (1 h)	14.6
9	PD test	1,73·U_0 (10 pC)	14.5
[a] Special test – May be performed if agreed between manufacturer and purchaser.			

11.6.3 Acceptance criteria

The electrical performance and mechanical integrity of the connector assembly shall remain within specified test and design limits throughout the test sequence. The acceptance criteria for each test are defined in the subclauses referenced in Table 19.

11.7 Hyperbaric test

11.7.1 Objective

This test sequence is to ensure that the connector assembly can tolerate repetitive surface recovery cycles without degradation or damage.

11.7.2 Sequence

The sequence of the hyperbaric type test shall be according to Table 20 for wet mateable connectors and Table 21 for dry mateable connectors. If penetrators are included in the set-up sequence in Table 20 or Table 21, the cycles performed can be counted towards the pressure cycling test that are required in 11.8.

The test media shall be derived from Table 8. The test media can be tap water if no wet-mate connectors are tested as part of the test.

Table 20 – Hyperbaric test sequence – Wet mateable connectors

Step	Test	Test level	Reference
1	Contact resistance	See test method	14.2
2	Insulation resistance	See test method	14.8
3	PD test	1,73·U_0 (10 pC)	14.5
4	Mate/de-mate/mate	At atmospheric pressure, dry conditions	
5	Submerge in test media		
6	Increase pressure, mated connectors		
7	Pressure cycling, mated	15 cycles to 1,1·RAP Hold time per cycle: 5 min	
8	De-mate/mate	25 repetitions at 1,1·RAP	
9	Reduce pressure to atmospheric, mated		
10	De-mate/mate/de-mate	At atmospheric pressure	
11	Increase pressure, de-mated connectors		
12	Pressure cycling, de-mated	15 cycles at 1,1·RAP Hold time per cycle: 5 min	N/A
13	Mate/de-mate	25 repetitions at 1,1·RAP	
14	Reduce pressure to atmospheric, de-mated		
15	Contact resistance	See test method	14.2
16	Insulation resistance	See test method	14.8
17	PD test	1,73·U_0 (10 pC)	14.5
18	High voltage AC test	2,5·U_0 (1 h)	14.6
19	PD test	1,73·U_0 (10 pC)	14.5

Table 21 – Hyperbaric test sequence – Dry mateable connectors

Step	Test	Test level	Reference
1	Contact resistance	See test method	14.2
2	Insulation resistance	See test method	14.8
3	PD test	1,73·U_0 (10 pC)	14.5
4	Mate/de-mate/mate	At atmospheric pressure, dry conditions	
5	Submerge in test media, increase pressure		
6	Pressure cycling (mated)	15 cycles at 1,1·RAP Hold time per cycle: 5 min	N/A
7	De-mate/mate	10 repetitions at atmospheric pressure, dry conditions	
8	Pressure cycling (mated)	15 cycles to 1,1·RAP Hold time per cycle: 5 min	N/A
9	Contact resistance	See test method	14.2
10	Insulation resistance	See test method	14.8
11	PD test	1,73·U_0 (10 pC)	14.5
12	High voltage AC test	2,5·U_0 (1 h)	14.6
13	PD test	1,73·U_0 (10 pC)	14.5

11.7.3 Acceptance criteria

The electrical performance and mechanical integrity of the connector assembly shall remain within the specified test and design limits throughout the test sequence. No leakage, degradation or damage shall be observed. The acceptance criteria for each of the tests are defined in the subclauses that are referenced in Table 20 and Table 21.

11.8 Pressure cycling test – Penetrators

11.8.1 Objective

This test is to demonstrate that the penetrator is capable of handling varying pressure loads in the worst-case operational conditions.

11.8.2 Sequence

The test sequence specified in Table 22 shall be performed as described. The penetrator shall be tested using a test media selected from Table 8 and at a temperature derived from the maximum in the penetrator's environmental classification as given in Table 4. This test should be conducted with the relevant cable and associated pressure compensators installed. The penetrator shall be installed in a manner that is representative of service conditions.

Table 22 – Pressure cycling test – Penetrators for pressure compensated equipment

Step	Test	Test level	Reference
1	Contact resistance	See test method	14.2
2	Insulation resistance	See test method	14.8
3	PD test	1,73·U_0(10 pC)	14.5
4	Static pressure test	1,5·10 bar Direction 1 and 2	14.16 Figure B.7/Figure B.8
5	Pressure cycling – Penetrators for pressure compensated equipment	50 cycles to 1,1·RAP at maximum temperature Allow sufficient time for pressure to stabilize	Figure B.6
6	Pressure cycling – Penetrators for pressure compensated equipment	50 cycles to 1,1·RAP at minimum temperature Allow sufficient time for pressure to stabilize	Figure B.6
7	Static pressure test	1,5·10 bar Direction 1 and 2	14.16 Figure B.7/Figure B.8
8	Pressure cycling – Penetrators for pressure compensated equipment	50 cycles to 1,1·10 bar at ambient temperature, direction 1 Allow sufficient time for pressure to stabilize	Figure B.7
9	Pressure cycling – Penetrators for pressure compensated equipment	50 cycles to 1,1·10 bar at ambient temperature, direction 2 Allow sufficient time for pressure to stabilize	Figure B.8
10	Insulation resistance	See test method	14.8
11	Contact resistance	See test method	14.2
12	PD test	1,73·U_0 (10 pC)	14.5
13	High voltage AC test	2,50·U_0 (1 h)	14.6
14	PD test	1,73·U_0 (10 pC)	14.5
Steps 8 and 9 may be skipped if combined with steps 5 or 6 (i.e. differential pressure is applied while applying absolute pressure).			

Table 23 – Pressure cycling test – Pressure retaining penetrators

Step	Test	Test level	Reference
1	Contact resistance	See test method	14.2
2	Insulation resistance	See test method	14.8
3	PD test	1,73·U_0 (10 pC)	14.5
4	Static pressure test	See test method – Direction 1 and 2	14.16 Figure B.3/Figure B.4
5	Pressure cycling – pressure retaining penetrators	50 cycles to 1,0·RAP-1 at max T – direction 1 Allow sufficient time for pressure to stabilize	Max T refers to the maximum temperature on the outboard side of the penetrator. Figure B.3
6	Pressure cycling – pressure retaining penetrators	50 cycles to 1,0·RAP-1 at min T – direction 1 Allow sufficient time for pressure to stabilize	Min T refers to the minimum temperature on the outboard side of the penetrator Figure B.3
7	Pressure cycling – pressure retaining penetrators	50 cycles to 1,0·RAP-2 at max T – direction 2 Allow sufficient time for pressure to stabilize	Max T refers to the maximum temperature on the inboard side of the penetrator Figure B.4
8	Pressure cycling – pressure retaining penetrators	50 cycles to 1,0·RAP-2 at at min T – direction 2 Allow sufficient time for pressure to stabilize	Min T refers to the minimum temperature on the inboard side of the penetrator Figure B.4
9	Static pressure test	See test method – Direction 1 and 2	14.16 Figure B.3/Figure B.4
10	Insulation resistance	See test method	14.8
11	Contact resistance	See test method	14.2
12	PD test	1,73·U_0 (10 pC)	14.5
13	High Voltage AC test	2,5·U_0 (1 h)	14.6
14	PD test	1,73·U_0 (10 pC)	14.5

11.8.3 Acceptance criteria

The electrical performance and mechanical integrity of the connector assembly shall remain within the specified test and design limits throughout the test sequence. No leakage, degradation or damage shall be observed. The acceptance criteria for each of the tests are defined in the subclauses that are referenced in Table 21 and Table 22.

11.9 Combined pressure and temperature cycling test – Penetrators

11.9.1 Objective

This test is to demonstrate that the penetrator is capable of handling varying pressure loads during varying temperature conditions. This test is mandatory for penetrators exposed to production gas/fluids in service.

11.9.2 Sequence

The test sequence shall be according to Table 24.

Table 24 – Combined pressure and temperature cycling test – Penetrators

Step	Test	Test level	Reference
1	Contact resistance	See test method	14.2
2	Insulation resistance	See test method	14.8
3	PD test	1,73·U_0 (10 pC)	14.5
4	Static pressure test	See test method – direction 1 and 2	14.16 Figure B.3/Figure B.4
5	Combined pressure and temperature cycling	For RAP-2 as a minimum Execute also for RAP – 1 if outboard side may be exposed to production fluids.	14.18 Figure B.4 (Figure B.3)
6	Static pressure test	See test method – direction 1 and 2	14.16 Figure B.3 /Figure B.4
7	Insulation resistance	See test method	14.8
8	Contact resistance	See test method	14.2
9	PD test	1,73·U_0 (10 pC)	14.5
10	High voltage AC test	2,50·U_0 (1 h)	14.6
11	PD test	1,73·U_0 (10 pC)	14.5

11.9.3 Acceptance criteria

The electrical performance and mechanical integrity of the assembly shall remain within the specified test and design limits throughout the test sequence. The acceptance criteria for each of the tests are defined in the clauses that are referenced in Table 24.

11.10 Rapid gas decompression test

11.10.1 Objective

This test is to verify that the connector assembly can withstand the specified decompression rate. This test sequence applies to components designed for exposure to production fluids. Detailed test conditions shall be agreed between the manufacturer and purchaser. The parts of the connector assembly that will be exposed to production fluids shall be included in the test.

11.10.2 Sequence

The sequence for the rapid gas decompression test shall be according to Table 25.

Table 25 – RGD test sequence

Step	Test	Test level	Reference
1	Contact resistance	See test method	14.2
2	Insulation resistance	See test method	14.8
3	PD test	1,73·U_0	14.5
4	Rapid gas decompression test	See test method	14.27
5	Static pressure test – penetrators	See test method	14.16
6	Contact resistance	See test method	14.2
7	Insulation resistance	See test method	14.8
8	PD test	1,73·U_0 (10 pC)	14.5

Step	Test	Test level	Reference
9	High voltage AC test	$2{,}50 \cdot U_0$(1 h)	14.6
10	PD test	$1{,}73 \cdot U_0$(10 pC)	14.5

11.10.3 Acceptance criteria

The electrical performance and mechanical integrity of the assembly shall remain within the specified test and design limits throughout the test sequence. No leakage, degradation or damage shall be observed. The acceptance criteria for each of the tests are defined in the subclauses that are referenced in Table 25.

11.11 Mechanical and environmental stress test

11.11.1 Objective

This test sequence is to ensure that the connector assembly can withstand the mechanical and environmental stresses and conditions it may experience during its design lifetime.

11.11.2 Sequence

The test sequence for the mechanical and environmental stress test shall be according to Table 26.

Table 26 – Mechanical and environmental stress test sequence

Step	Test	Test level	Reference
1	Contact resistance	See test method	14.2
2	Insulation resistance	See test method	14.8
3	PD test	$1{,}73 \cdot U_0$ (10 pC)	14.5
4	Thermal shock test (B)	See test method	14.9
5	Contact resistance (B)	See test method	14.2
6	PD test (B)	$1{,}73 \cdot U_0$ (10 pC)	14.5
7	Bending moment and free fall tests (P)	See test method	14.15
8	PD test	$1{,}73 \cdot U_0$ (10 pC)	14.5
9	Shock and vibration test (P)	See test method	14.19
10	PD test	$1{,}73 \cdot U_0$ (10 pC)	14.5
11	Static pressure test (penetrators only)	See test method. Relevant direction(s)	14.16
12	Conductor pull test (P)	See test method	14.21
13	PD test	$1{,}73 \cdot U_0$ (10 pC)	14.5
14	Contact resistance test	See test method	14.2
15	Cable pull test (P)	See test method	14.21
16	Contact resistance test	See test method	14.2
17	PD test	$1{,}73 \cdot U_0$ (10 pC)	14.5
18	Cable termination bending test	See test method	14.23
19	Contact resistance test	See test method	14.2
20	PD test	$1{,}73 \cdot U_0$ (10 pC)	14.5
21	Cleaning and spillage test (P)	See test method	14.20
22	Contact resistance	See test method	14.2

Step	Test	Test level	Reference
23	Insulation resistance	See test method	14.8
24	PD test	1,73·U_0 (10 pC)	14.5
25	High voltage AC test	2,5·U_0 (1 h)	14.6
26	PD test	1,73·U_0 (10 pC)	14.5
(B) mandatory tests, performed in specified sequence. (P) mandatory tests; can be performed in parallel on separate test specimen.			

11.11.3 Acceptance criteria

The electrical performance and mechanical integrity of the connector assembly shall remain within the specified test and design limits throughout the test sequence. No leakage, degradation or damage shall be observed. The acceptance criteria for each of the tests are defined in the subclauses that are referenced in Table 26.

11.12 Endurance test – Connectors

11.12.1 Objective

This test is to demonstrate robustness by applying voltage and current at maximum ambient temperature for a longer period.

11.12.2 Sequence

The test sequence for the endurance test shall be as given in Table 27. Unless otherwise agreed between manufacturer and purchaser, the test shall be performed at the following conditions:

- maximum ambient temperature as defined in Table 4;
- representative test media as defined in Table 8;
- rated absolute pressure;
- rated voltage;
- rated current.

Table 27 – Endurance test – Connectors

Step	Test	Test level	Reference
1	Contact resistance	See test method	14.2
2	Insulation resistance	See test method	14.8
3	PD test	1,73·U_0 (10 pC)	14.5
4	De-mate/Mate		
5	Endurance test, mated condition, 250 h	Long term test at RAP (constant pressure)	N/A
6a	De-mate/Mate – wet mateable connectors only	50 repetitions (submerged, at RAP)	
6b	De-mate/Mate – dry mateable connectors only	10 repetitions (dry, atmospheric conditions)	
7	Endurance test, mated condition, 250 h	Long term test at RAP (constant pressure	N/A
8	Contact resistance	See test method	14.2
9	Insulation resistance	See test method	14.8
10	PD test	1,73·U_0 (10 pC)	14.5

Step	Test	Test level	Reference
11	High voltage AC test	2,50·U_0 (1 h)	14.6
12	PD test	1,73·U_0 (10 pC)	14.5

11.12.3 Acceptance criteria

The electrical performance and mechanical integrity of the connector assembly shall remain within the specified test and design limits throughout the test sequence. No leakage, degradation or damage shall be observed. The acceptance criteria for each of the tests are defined in the subclauses that are referenced in Table 27.

11.13 Endurance test – Penetrators

11.13.1 Objective

This test is to demonstrate robustness by applying voltage, current and differential pressure at maximum ambient temperature for a longer period.

11.13.2 Sequence

The test sequence specified in Table 28 shall be performed with differential pressure applied in both directions (internal-ambient and ambient-internal), in total two test sequences. Unless otherwise agreed between manufacturer and purchaser, the test shall be performed at the following conditions:

- maximum ambient temperature as defined in Table 4;
- representative test media as defined in Table 8;
- rated absolute pressure;
- rated voltage;
- rated current.

Table 28 – Endurance test – Pressure retaining penetrators

Step	Test	Test level	Reference
1	Contact resistance	See test method	14.2
2	Insulation resistance	See test method	14.8
3	PD test	1,73·U_0 (10 pC)	14.5
4	Static pressure test	See test method – direction 1	14.16 Figure B.3
5	Endurance test, 250 h	Constant pressure, RAP-1	Maximum ambient temperature refers to the maximum temperature at the outboard side of the penetrator. Figure B.3 This test may be combined with endurance test for connectors
6	Static pressure test	See test method Use 24 h hold time in step 7 of the test procedure, direction 1	14.16 Figure B.3
7	Contact resistance	See test method	14.2
8	Insulation resistance	See test method	14.8

Step	Test	Test level	Reference
9	PD test	1,73·U_0 (10 pC)	14.5
10	High voltage AC test	2,5·U_0 (1 h)	14.6
11	PD test	1,73·U_0 (10 pC)	14.5
12	Static pressure test	See test method, direction 2	14.16 Figure B.4
13	Endurance test, 250 h	Constant pressure, RAP-2	Maximum ambient temperature refers to the maximum temperature at the inboard side of the penetrator. Figure B.4
14	Static pressure test	See test method Use 24 h hold time in step 7 of the test procedure, direction 2	14.16 Figure B.4
15	Contact resistance	See test method	14.2
16	Insulation resistance	See test method	14.8
17	PD test	1,73·U_0 (10 pC)	14.5
18	High voltage AC test	2,50·U_0 (1 h)	14.6
19	PD test	1,73·U_0 (10 pC)	14.5

Table 29 – Endurance test – Penetrators for pressure compensated equipment

Step	Test	Test level	Reference
1	Contact resistance	See test method	14.2
2	Insulation resistance	See test method	14.8
3	PD test	1,73·U_0 (10 pC)	14.5
4	Static pressure test	See test method – direction 1 and 2	14.16 Figure B.7 and Figure B.8
5	Endurance test, 500 h	Constant pressure, RAP	Figure B.6
6	Static pressure test	See test method Use 24 h hold time in step 7 of the test procedure Direction 1 and 2	14.16 Figure B.7 and Figure B.8
7	Contact resistance	See test method	14.2
8	Insulation resistance	See test method	14.8
9	PD test	1,73·U_0 (10 pC)	14.5
10	High voltage AC test	2,50·U_0 (1 h)	14.6
11	PD test	1,73·U_0 (10 pC)	14.5

11.13.3 Acceptance criteria

The electrical performance and mechanical integrity of the connector assembly shall remain within the specified test and design limits throughout the test sequence. No leakage, degradation or damage shall be observed. The acceptance criteria for each of the tests are defined in the references in Table 28 and Table 29.

11.14 Inner water seal hyperbaric test – Connectors

11.14.1 Objective

This test is to ensure that the connector assembly can withstand operational conditions with the outer water seal removed, without degradation or damage.

11.14.2 Sequence

Test sequence shall be according to 11.7.2. In some cases, it is not practical to remove the seal(s) itself, but the sealing function shall be compromised such that the volume(s) affected by the applicable seal(s) is(are) completely filled with the conductive test media that has been selected from Table 8.

11.14.3 Acceptance criteria

The electrical performance and mechanical integrity of the connector assembly shall remain within the specified test and design limits throughout the test sequence. No leakage, degradation or damage shall be observed. The acceptance criteria for each of the tests are defined in the subclauses that are referenced in Table 20 and Table 21.

11.15 Inner water seal pressure cycling test – Penetrators

11.15.1 Objective

This test is to ensure that the connector assembly is able to withstand operational conditions with the outer water seal removed, without degradation or damage.

11.15.2 Sequence

Test sequence shall be according to 11.8.2. In some cases, it is not practical to remove the seal(s) itself, but the sealing function shall be compromised such that the volume(s) affected by the applicable seal(s) is(are) completely filled with the conductive test media.

11.15.3 Acceptance criteria

The electrical performance and mechanical integrity of the assembly shall remain within the specified test and design limits throughout the test sequence. No leakage, degradation or damage shall be observed. The acceptance criteria for each of the tests are defined in the clauses that are referenced in Table 22 and Table 23.

11.16 Outer water seal hyperbaric test – Connectors

11.16.1 Objective

This test is to ensure that the connector assembly is able to withstand operational conditions with the inner water seal removed, without degradation or damage.

11.16.2 Sequence

Test sequence shall be according to 11.7.2. In some cases, it is not practical to remove the seal(s) itself, but the sealing function shall be compromised such that the volume(s) affected by the applicable seal(s) is(are) completely filled with the test media present between outer and inner seals.

11.16.3 Acceptance criteria

The electrical performance and mechanical integrity of the assembly shall remain within the specified test and design limits throughout the test sequence. No leakage, degradation or damage shall be observed. The acceptance criteria for each of the tests are defined in the subclauses that are referenced in Table 20 and Table 21.

11.17 Outer water seal pressure cycling test – Penetrators

11.17.1 Objective

This test is to ensure that the connector assembly is able to withstand operational conditions with the inner water seal removed, without degradation or damage.

11.17.2 Sequence

Test sequence shall be according to 11.8.2. In some cases, it is not practical to remove the seal(s) itself, but the sealing function shall be compromised such that the volume(s) affected by the applicable seal(s) is(are) completely filled with the test media present between outer and inner seals.

11.17.3 Acceptance criteria

The electrical performance and mechanical integrity of the assembly shall remain within the specified test and design limits throughout the test sequence. No leakage, degradation or damage shall be observed. The acceptance criteria for each of the tests are defined in the references in Table 22 and Table 23.

11.18 Secondary pressure integrity seal test – Penetrators

11.18.1 Objective

This test is to demonstrate that the penetrator is capable of handling operational loads with the primary pressure integrity seal removed, without degradation or damage.

11.18.2 Sequence

Test sequence shall be according to 11.8.2. In some cases, it is not practical to remove the seal(s) itself, but the sealing function shall be compromised such that the volume(s) affected by the applicable seal(s) is(are) completely filled with the test media.

11.18.3 Acceptance criteria

The electrical performance and mechanical integrity of the assembly shall remain within the specified test and design limits throughout the test sequence. No leakage, degradation or damage shall be observed. The acceptance criteria for each of the tests are defined in the references in Table 22 and Table 23.

11.19 Primary pressure integrity seal test – Penetrators

11.19.1 Objective

This test is to demonstrate that the penetrator is capable of handling operational loads with the secondary pressure integrity seal removed, without degradation or damage.

11.19.2 Sequence

Test sequence shall be according to 11.8.2. In some cases, it is not practical to remove the seal(s) itself, but the sealing function shall be compromised such that the volume(s) affected by the applicable seal(s) is(are) completely filled with the test media.

11.19.3 Acceptance criteria

The electrical performance and mechanical integrity of the assembly shall remain within the specified test and design limits throughout the test sequence. No leakage, degradation or damage shall be observed. The acceptance criteria for each of the tests are defined in the references in Table 22 and Table 23.

11.20 Secondary pressure integrity seal combined pressure and temperature cycling test – Penetrators

11.20.1 Objective

This test is to demonstrate that the penetrator is capable of handling varying pressure loads in the worst-case operational conditions – with the primary pressure integrity seal removed. The penetrators shall be installed at actual operational conditions (media and max./min. temperature).

11.20.2 Sequence

Test sequence shall be according to 11.9.2. In some cases, it is not practical to remove the seal(s) itself, but the sealing function shall be compromised such that the volume(s) affected by the applicable seal(s) is(are) completely filled with the test media.

11.20.3 Acceptance criteria

The electrical performance and mechanical integrity of the assembly shall remain within the specified test and design limits throughout the test sequence. The acceptance criteria for each of the tests are defined in the references in Table 24.

11.21 Primary pressure integrity seal combined pressure and temperature cycling test – Penetrators

11.21.1 Objective

This test is to demonstrate that the penetrator is capable of handling varying pressure loads in the worst-case operational conditions and with the secondary pressure integrity seal removed. The penetrator shall be installed in a manner that is representative of service conditions. The penetrator shall be tested using a test media selected from Table 8 and at a temperature derived from the maximum in the penetrator’s environmental classification as given in Table 4.

11.21.2 Sequence

Test sequence shall be according to 11.9.2. In some cases, it is not practical to remove the seal(s) itself, but the sealing function shall be compromised such that the volume(s) affected by the applicable seal(s) is(are) completely filled with the test media.

11.21.3 Acceptance criteria

The electrical performance and mechanical integrity of the assembly shall remain within the specified test and design limits throughout the test sequence. The acceptance criteria for each of the tests are defined in the references in Table 23.

11.22 Extended hyperbaric wet mate test

11.22.1 Objective

This test is to demonstrate the design margins of a wet mate connector system (robustness). This is a special test applicable to wet mateable connectors.

11.22.2 Sequence

The sequence for the extended hyperbaric shall be according to Table 30.

The test media shall be derived from Table 8. The temperature shall be in the range 0 ºC to 5 ºC.

The connector shall be mounted in a special test rig for performing mating operations in a manner that simulates normal mounting. Both a vertical mounting and a horizontal mounting are considered base cases, but consideration shall be given with respect to the application for connector and worst-case angles. Alternative angles or tilting of connector in test can be relevant dependent on the actual application.

Unless otherwise agreed between manufacturer and purchaser, electrical tests as specified in Table 9 shall be performed where "electrical tests" are specified in the test sequence.

During each de-mate operation, the connectors shall remain fully de-mated (as defined in the definitions) for a period of no less than 1 min. The number of mating operations shall be as specified in Table 30. The test sequence shall be terminated if any of the acceptance criteria of the electrical tests are not fulfilled.

Trend curves for all electrical test results shall be established.

Upon completion of the test sequence, the connectors shall be examined externally for damage and defects.

Table 30 – Extended hyperbaric wet mate test sequence

Step	Test	Test level	Reference
1	Mate	Dry conditions	
2	Electrical tests	See test method	Table 9
3	De-mate/mate	Dry conditions	
4	Electrical tests		Table 9
5	De-mate/mate	Submerged, atmospheric pressure	
6	Electrical tests		Table 9
7	De-mate	Submerged, atmospheric pressure	
8	Increase pressure, de-mated connectors	To 0,5·RAP	
9	Mate/de-mate/mate	At 0,5·RAP	
10	Electrical tests		Table 9
11	De-mate	At 0,5·RAP	
12	Increase pressure, de-mated connectors	To 1,0·RAP	
13	Mate/de-mate/mate	At 1,0·RAP	
14	Electrical tests		
15	Hold pressure for 60 min – then reduce to atmospheric pressure – mated connectors		
16	Repeat step 4 to step 15		
17	Electrical tests	Atmospheric pressure	Table 9
18	De-mate/mate	Submerged, atmospheric pressure	
19	Electrical tests		Table 9
20	Increase pressure, mated connectors	To 0,5·RAP	
21	De-mate/mate	At 0,5·RAP	
22	Electrical tests		Table 9
23	Increase pressure, mated connectors	To 1,0·RAP	
24	De-mate/mate	At 1,0·RAP	
25	Electrical tests		Table 9
26	De-mate	At 1,0·RAP	
27	Hold pressure for 60 min – then reduce to atmospheric pressure – de-mated connectors		

Step	Test	Test level	Reference
28	Repeat step 17 to step 27		
29	Mate	At atmospheric pressure	
30	Electrical tests	At atmospheric pressure	Table 9
31	De-mate/mate/de-mate	At atmospheric pressure	
32	Increase pressure, de-mated connectors	To 1,0·RAP	
33	40 x mate/de-mate, electrical tests after every 5th cycle	At 1,0·RAP	
34	Hold pressure for 60 min – then reduce to atmospheric pressure – de-mated connectors		
35	Mate	At atmospheric pressure	
36	Electrical tests	At atmospheric pressure	Table 9
37	Increase pressure, mated connectors	To 1,0·RAP	
38	40 x de-mate/mate, electrical tests after every 5th cycle	At 1,0·RAP	
39	Hold pressure for 60 min – then reduce to atmospheric pressure –mated connectors		
40	Electrical tests	At atmospheric pressure	Table 9

11.22.3 Acceptance criteria

The electrical performance and mechanical integrity of the assembly shall remain within the specified test and design limits throughout the test sequence. The acceptance criteria for each of the tests are defined in the references in Table 24.

12 Type tests – Hose and hose terminations

12.1 General

A hose and its associated terminations shall be type tested as stand-alone items independent of the connector and penetrator test procedures. Unless otherwise specified, the cable is not included in these tests. The type test sequence for hoses and hose terminations is given in Table 31.

Table 31 – Hose type test sequence

Summary of hose and hose termination type tests		
Test type	**Type test**	**Reference**
Material tests	Material type tests	14.28
Environmental stress tests	Absorption/compensation test	12.2
	Ozone resistance	12.3
	Ultraviolet resistance	12.4
	Thermal shock	12.5
Destructive testing	Tensile failure [a]	12.6.1
	Burst pressure [a]	12.6.2
	Crush resistance	12.6.3
	Outer sheath abrasion	12.6.4
	Hose kink testing	12.6.5

[a] This test shall also be performed as a sample test (refer to Clause 10).

12.2 Absorption/compensation test

12.2.1 Objective

This test is to determine the compensation and ageing characteristics of a conduit hose filled with insulating oil and immersed in sea water at rated absolute pressure. Ageing is accelerated using high temperature. This test is also used to determine the amount of volume that the hose can compensate.

12.2.2 Method

A hose assembly consisting of at least a two-metre length of hose, a pressure transducer (for monitoring hose internal pressure) and end caps shall be filled with the relevant compensation fluid and pressurised to the specified internal pressure. The dielectric strength and water content of the compensation fluid shall be recorded prior to the test. The hose termination fittings shall be identical to the type used in production jumper assemblies. The assembly shall be placed within a pressure vessel and pressurised according to the test pressure below. For sea water applications, the test parameters shall be:

– vessel fluid: artificial sea water as defined in 6.3;
– vessel fluid temperature: 60 °C;
– test pressure: 1,1· RAP.

For applications in other fluids or at other temperatures, the assembly shall be tested in the relevant fluid according to Table 8 at the worst-case conditions defined by Table 4; in this case, the test parameters shall be agreed between the manufacturer and purchaser.

Monitor and record the following parameters daily over a period of 14 days (336 h):

– vessel pressure;
– internal hose pressure;
– vessel temperature.

A calculation shall be performed to determine how much uncompensated volume per length the hose can compensate throughout the pressure and temperature range.

Electronic data storage or a chart recorder with a suitable number of channels is preferred to record the values. The recording shall be set up to detect any large deviation in the conditions of the test and to detect any important intermittent deviation in the recorded results. Alternatively, manual instruments with recordings at the beginning and at the end of each working day are required. At the end of the test period, the hose shall be allowed to return to ambient temperature, the vessel pressure shall be released, and the assembly removed from the test vessel. The hose shall be inspected for damage and defects.

The dielectric strength and water content of the compensation fluid shall be recorded after the test and compared with the results obtained prior to the test, to evaluate if there has been a significant degradation in the insulating properties of the fluid.

12.2.3 Acceptance criteria

a) The hose shall be free from damage or defects. All observations shall be documented within the type test report.
b) The dielectric strength of the compensating fluid within the hose shall be measured by means of breakdown voltage and volume resistivity. These figures shall not change more than 5 % from original values to denote no water ingress.
c) No free water shall be observed.
d) A net positive pressure shall be maintained within the hose throughout the test duration.

12.3 Ozone resistance

12.3.1 Objective

This test is to verify the resistance of the hose to damage from ozone.

12.3.2 Method

The hose sheath resistance to ozone shall be tested and documented in accordance with ISO 7326:2016. At least three test samples shall be tested in accordance with method 2 of ISO 7326. The ozone concentration shall be 50 pphm ± 5 pphm[2] at 40 ± 2 °C for 72 h.

The strain in the test samples shall not be less than the maximum hose strain anticipated in service (induced at the MBR). A strain of 20 % may be used if the MBR is not specified.

Examine the test pieces after 2 h, 4 h, 8 h, 24 h and 72 h.

12.3.3 Acceptance criteria

The samples shall be free from any visual damage and cracks.

12.4 Ultraviolet resistance

12.4.1 Objective

This test is to verify the resistance of the hose sheath to damage from ultraviolet light.

12.4.2 Method

The resistance of the hose sheath to ultraviolet light shall be tested and documented in accordance with ISO 30013:2011. At least three test samples of type 2 ISO 30013 shall be tested.

The strain in the sheath of the test samples shall not be less than the maximum strain anticipated in service (induced at the MBR). A strain of 20 % may be used if the MBR is not specified.

The test shall be performed in accordance with Table 2, method A, cycle no. 1 of ISO 30013:2011, i.e. ultraviolet light source with a wavelength 300 nm to 400 nm at an irradiance level of 60 W/m^2 ± 2 W/m^2. The number of cycles (dry and water spray) shall represent a minimum of 1 000 h testing.

Ultraviolet light tests shall be performed on the following samples:

– three new unexposed test samples;

– three test samples already exposed to ozone (refer to 12.3).

12.4.3 Acceptance criteria

a) The samples shall be visibly inspected and be free from any damage and cracks. If cracking is discovered, the sample will be deemed to have failed the test. The cracks shall be photographed and recorded in the type test report.

b) Colour changes are permitted and shall be documented in the type test report.

2 pphm = parts per hundred million

12.5 Thermal shock test

12.5.1 Objective

This test is to verify that thermal shock has no detrimental effects on the hose assembly.

12.5.2 Method

12.5.2.1 General

A hose assembly consisting of at least a 2 m length of hose, a pressuAre transducer (for monitoring hose internal pressure) and end caps shall be filled with the relevant compensation fluid and pressurised to the specified internal pressure. The hose termination fittings shall be identical to the type used in production jumper assemblies. The hose shall then be coiled to its minimum bend radius and held in position using cable ties.

The tests shall be performed at atmospheric pressure.

12.5.2.2 High temperature

The hose assembly temperature shall be raised to 60 °C and maintained for a period of 4 h. The hose assembly shall then be rapidly cooled by immersion in a water bath, the temperature of which shall be between 0 °C and 5 °C.

The above sequence shall be repeated two times. Allow the hose assembly to return to room temperature.

The assembly shall be inspected for physical damage and all observations recorded.

12.5.2.3 Low temperature

The hose assembly temperature shall be lowered to −25 °C and maintained for a period of 4 h. The hose assembly shall then be rapidly heated by immersion in a water bath, the temperature of which shall be between 0 °C and 5 °C.

The above sequence shall be repeated two times. Allow the hose assembly to return to ambient room temperature.

The assembly shall be inspected for physical damage and all observations recorded.

12.5.3 Acceptance criteria

The hose assembly will be considered acceptable if no physical damage is observed.

Any changes to the internal pre-charge pressure identified during the test shall be recorded and explained within the type test report.

12.6 Destructive testing

12.6.1 Tensile failure

12.6.1.1 Objective

This test is to establish the failure load of the hose or associated hose fittings.

12.6.1.2 Method

A hose assembly consisting of at least a two-metre length of hose, hose fittings and end caps shall be filled with the relevant compensation fluid and pressurised to the specified internal pressure. The hose termination fittings shall be identical to the type to be used in production jumper assemblies.

The test shall be performed as a simple pull test with force applied at 0° to the termination. The tensile load shall be increased in a gradual manner until failure of the hose or hose fittings occur. At the point of failure, the following parameters shall be recorded:

– hose elongation;
– applied tensile load at point of failure.

When performing this as a batch test, there shall be no requirement for oil filling of the hose.

12.6.1.3 Acceptance criteria

The hose assembly shall be considered acceptable if the point of failure is greater than the specified minimum breaking strength (which shall be greater than 5 000 N). Any observations shall be documented in the type test report.

12.6.2 Burst pressure

12.6.2.1 Objective

This test is to verify the pressure containment performance of hose and associated hose fittings.

12.6.2.2 Method

A hose assembly consisting of at least a two-metre length of hose, hose fittings and end caps shall be internally pressurised with tap water until failure of hose or hose fittings occurs. The pressure at which failure occurs shall be recorded.

12.6.2.3 Acceptance criteria

The hose assembly shall be considered acceptable if the point of failure is greater than the specified burst pressure.

12.6.3 Crush resistance

12.6.3.1 Objective

This test is to establish any detrimental effects that may occur due to the hose being crushed flat and to ascertain if the hose is usable after such an incident.

12.6.3.2 Method

A sample of hose with a minimum length of 0,5 m shall be selected. The hose shall be empty and open at both ends. Testing and measurements shall be undertaken at room temperature. The outer hose diameter shall be recorded at a known point at the mid-section of the sample. The mid-section shall then be compressed between two metal plates so that the point at which the diameter was measured is perpendicular to the surface of the plates and crushed completely flat. The metal plates used shall be square, have a minimum thickness of 5 mm, have edges with an approximate radius of 1,5 mm and be sufficient to withstand the forces applied without visible signs of deformation. The dimensions of the square plates shall be selected as described below:

– initial hose diameter 50 mm or less: 80 mm × 80 mm;
– initial hose diameter 51 mm to 90 mm: 150 mm × 150 mm;

– initial hose diameter 91 mm to 180 mm: 300 mm × 300 mm;
– greater than 180 mm: A mm × A mm where A = 1,6 times the initial diameter of the hose.

Compression may be achieved by using a vice or compression test machine to act on the plates or by adding weights to one plate with the other on a flat surface, so as to collapse the hose completely. The hose shall remain completely compressed for 24 h after which the force shall be removed. The outer diameter of the hose at the original measuring point shall be re-measured 4 h after removal of the force.

The following parameters shall be recorded:

– initial outer diameter of the hose at the measuring point;
– outer diameter of hose at the same measuring point 4 h after removal of the force.

12.6.3.3 Acceptance criteria

The hose assembly shall be considered acceptable if no visible damage is apparent (e.g. cracking, splitting or delamination) and the hose returns to at least 50 % of the initial diameter within the 4-h measuring period. Any observations shall be included in the type test report.

12.6.4 Outer sheath abrasion resistance

12.6.4.1 Objective

The aim of this test is to establish the abrasion resistance of the jumper assembly to ensure that it is sufficiently durable for handling and installation.

12.6.4.2 Method

A minimum 1 m length of hose or cable (if it is a cable jumper with no hose) shall be selected. Where a hose is used, it shall be empty and open at both ends. The sample shall be positioned over a turned steel tube with a diameter equal to the minimum bend radius of the hose or cable and having a surface roughness Ra of at least 12,5 µm (500 µin) so that the sample forms an angle of approximately 90° across the tube. The sample shall be pulled back and forth, and simultaneously side to side for 100 cycles across the mid-section along a 100 mm length with a force of approximately 250 N.

12.6.4.3 Acceptance criteria

The outer sheath shall not have been penetrated within the 100 mm abrasion area (armour or inner layer shall not be visible).

12.6.5 Hose kink test

12.6.5.1 Objective

This test is to establish the bend radius at which the fluid filled hose collapses and to ascertain if the hose recovers after such an incident.

12.6.5.2 Method

A hose assembly consisting of at least a 2 m length of hose, hose fittings and end caps shall be filled with the relevant compensation fluid and pressurised to the specified internal pressure. The hose termination fittings shall be identical to the type to be used in production jumper assemblies.

The hose shall then be positioned in a loop such that the bend radius can be adjusted. The loop shall then be tightened to the point at which the hose collapses. The bend radius at which the collapse occurs shall be recorded.

12.6.5.3 Acceptance criteria

The hose assembly shall be considered acceptable if no visible damage is apparent and the hose returns to its original form.

The radius at which the hose collapses shall be equal to or less than 6 times the hose outside diameter. The radius at which the hose collapses shall also be less than the stated minimum bend radius of the hose.

13 Type tests – Jumper assemblies

13.1 General

These tests are to verify that the completed jumper assembly comprising of connectors, hose, hose termination fittings and electrical cables perform as intended when integrated together.

All jumper testing shall be performed with a jumper assembly terminated at both ends with connectors and filled to the specified pre-charge pressure with the specified compensation medium. In addition to this, two bulkhead connector assemblies shall also be required. The length of the jumper shall be sufficient to establish a figure eight at the minimum bending radius, plus 2 m (1 m at each end to allow for termination).

For type tests of jumpers significantly longer than the length defined within this document, alternative test methods may be more applicable or appropriate. In this case, the manufacturer and purchaser shall agree upon additional testing that may be required.

An overview of the test sequence is shown in Table 32.

Table 32 – Jumper assembly type test sequence

Jumper assembly type testing		
Test type	**Type test**	**Clause**
Material test	Material type tests	14.28
Jumper assembly tests	Electrical and thermal type test – Jumpers	13.2
	Oscillating jumper test	13.3
	Jumper pull test	13.4
	Drop test	13.5
	Jumper handling simulation test	13.6
	Simulated deployment test	13.7

13.2 Electrical and thermal type test – Jumper assemblies

13.2.1 Objective

This test is to ensure that the complete assembly can effectively deal with load changes, both at and without hyperbaric pressure. Information about capability for operation in air will also be determined. This test may be combined with thermal type tests for connectors and/or penetrators (see 11.5).

13.2.2 Sequence

The test sequence for the electrical and thermal type test for jumper assemblies shall be according to Table 33.

Table 33 – Electrical and thermal type test – Jumper assemblies

Step	Test	Test level	Reference
1	Contact resistance	See test method	14.2
2	Insulation resistance	See test method	14.8
3	PD test	1,73·U_0 (10 pC)	14.5
4	Temperature rise test	See test method	14.12
5	Thermal cycles	15 cycles at RAP	14.14
6a	Thermal cycles – Class I, II and III	30 cycles at 1,1·RAP	14.14
6b	Thermal cycles – Class IV	60 cycles at 1,1·RAP	14.14
7	Contact resistance	See test method	14.2
8	Insulation resistance	See test method	14.8
9	PD test	1,73·U_0 (10 pC)	14.5
10	High voltage AC test	2,5·U_0 (1 h)	14.6
11	PD test	1,73·U_0 (10 pC)	14.5

13.2.3 Acceptance criteria

The electrical performance of the assembly shall remain within specified design limits throughout the test sequence. The acceptance criteria for each of the tests are defined in the subclauses that are referenced in Table 33.

13.3 Oscillating jumper test

13.3.1 Objective

This test is to verify that the complete jumper assembly is sufficiently durable to oscillations that may occur in service.

13.3.2 Sequence

The test sequence for the oscillating jumper test shall be according to Table 34.

Table 34 – Oscillating jumper test

Step	Test	Test level	Reference
1	Contact resistance	See test method	14.2
2	Insulation resistance	See test method	14.8
3	PD test	1,73·U_0 (10 pC)	14.5
4	Oscillating jumper test	See below	
6	Contact resistance	See test method	14.2
7	PD test	1,73·U_0 (10 pC)	14.5
8	High voltage AC test	2,50·U_0 (1 h)	14.6
9	PD test	1,73·U_0 (10 pC)	14.5

The test shall utilise a bulkhead mounted connector mounted securely within a test tank containing artificial sea water produced according to 6.3. One end of the jumper assembly shall be mated with the bulkhead connector through which electrical tests can be performed. The other end of the jumper shall be free to move. The jumper should be moved in a conical rotation, which describes a solid angle of 30° at a distance conforming to the minimum design bending radius in the data sheet. The rotation shall be achieved by supporting the jumper through a ring mounted on a rotating mechanical arm. This mechanical arm shall rotate on its axle around the bulkhead connector's own axis.

The frequency should be approximately four rotations per minute lasting for 30 days, (equivalent 170 000 cycles). Insulation resistance and contact resistance should be monitored regularly.

13.3.3 Acceptance criteria

There shall be no damage to the jumper. The acceptance criteria for each of the tests are defined in the subclauses that are referenced in Table 34.

13.4 Jumper pull test

13.4.1 Objective

This test is to ensure that the connector and associated jumper assembly are constructed with sufficient strain relief and mechanical strength to withstand the forces it might at worst-case be subjected to, such as a snagged jumper during assembly. The test shall verify the pull strength to be greater than the stated working maximum.

13.4.2 Sequence

The sequence for the jumper pull test shall be according to Table 35.

Table 35 – Jumper pull test

Step	Test	Test level	Reference
1	Measure jumper length		
2	Contact resistance	See test method	14.2
3	Insulation resistance	See test method	14.8
4	PD test	1,73·U_0 (10 pC)	14.5
5	Jumper pull test	See below	
6	Contact resistance	See test method	14.2
7	PD test	1,73·U_0 (10 pC)	14.5
8	High voltage AC test	2,50·U_0 (1 h)	14.6
9	PD test	1,73·U_0 (10 pC)	14.5
10	Measure jumper length		

The test shall be performed as a simple pull test with a force applied sequentially in one axis at a time in three perpendicular axes to the outlet of the hose. The mechanical mechanism that restrains the hose and prevent exceeding the MBR shall be held rigid. The force applied shall be in Newtons equal to 60 times the total cross-sectional area of (all) the cable(s) in the hose (in mm^2) up to a maximum of 5 kN. With the maximum force applied, the cable/hose total elongation shall be recorded.

13.4.3 Acceptance criteria

No damage to the jumper shall be observed. The jumper shall return to the original length (prior to the pull test) after a sufficient relaxation period, typically 15 min.

The acceptance criteria for each of the tests are defined in the subclauses that are referenced in Table 35.

13.5 Drop test

13.5.1 Objective

This test is to verify that the jumper assembly is sufficiently rugged to withstand rough handling and the loads which may be generated during an accidental drop.

13.5.2 Sequence

The sequence for the drop test shall be according to Table 36.

Table 36 – Drop test

Step	Test	Test level	Reference
1	Contact resistance	See test method	14.2
2	Insulation resistance	See test method	14.8
3	PD test	$1{,}73 \cdot U_0$ (10 pC)	14.5
4	Drop test	See below	
5	Contact resistance	See test method	14.2
6	PD test	$1{,}73 \cdot U_0$ (10 pC)	14.5
7	High voltage AC test	$2{,}50 \cdot U_0$ (1 h)	14.6
8	PD test	$1{,}73 \cdot U_0$ (10 pC)	14.5

Each end of the jumper assembly (excluding the mass of the suspended cable or hose) shall be subjected to a free fall test in accordance with IEC 60721-3-2:2018, Table 5, class 2M5. The floor shall be hard, typically as for a transport compartment. Protection caps shall be assembled, as required.

13.5.3 Acceptance criteria

No damage shall be observed on either connector that would interfere with their normal operation. It shall be possible to mate and de-mate both connectors with the test connector. Damage to the protective cover, if used, is permissible. The acceptance criteria for each of the tests are defined in the subclauses that are referenced in Table 36.

13.6 Jumper handling simulation test

13.6.1 Objective

This test is to verify that the assembled connector and associated jumper assembly is sufficiently designed to withstand normal handling loads during workshop handling and installation.

13.6.2 Sequence

The sequence for the jumper handling simulation test shall be according to Table 37.

Table 37 – Jumper handling simulation test

Step	Test	Test level	Reference
1	Contact resistance	See test method	14.2
2	Insulation resistance	See test method	14.8
3	PD test	$1,73 \cdot U_0$ (10 pC)	14.5
4	Jumper handling test	See below	
5	Contact resistance	See test method	14.2
6	PD test	$1,73 \cdot U_0$ (10 pC)	14.5
7	High voltage AC test	$2,50 \cdot U_0$ (1 h)	14.6
8	PD test	$1,73 \cdot U_0$ (10 pC)	14.5

If a hose jumper is being evaluated, it shall be pressurized with the normal compensation fluid and a pressure gauge attached to allow monitoring of the pressure during the test. The internal hose pressure shall be monitored and recorded during the entire coiling operation.

The jumper assembly shall be coiled in a figure of eight pattern (3 turns) such that the recommended minimum coiling radius, recommended minimum distance between centerlines of the figure eight coils and uncoiled jumper length are achieved. Rotation of the jumper termination during coiling shall be prevented to allow development of the torsional loads. The jumper should then be uncoiled and laid out straight. This procedure shall then be repeated. Refer to Figure 1.

The jumper supplier shall recommend requirements and parameters for coiling jumper in the figure eight pattern and specify:

- horizontal, vertical, both or any orientation of the figure eight pattern;
- jumper minimum bend radius for figure eight coil (R);
- minimum distance between centerlines of the figure eight coils (D);
- minimum length of the uncoiled jumper (L) which is remaining, not coiled length of the jumper when figure eight coiling is complete;
- maximum suspended length of the jumper in air.

The jumper shall have sufficient length to complete 3 complete turns of the horizontal figure eight pattern plus the minimum length of the uncoiled jumper (L). The jumper shall be constrained to prevent torsional rotation at the first tangential point of the figure eight. The length of the jumper measured from constraint point shall be selected to complete 3 turns and not to exceed minimum uncoiled jumper length (L).

The jumper termination shall be positioned vertically during 3 turn coiling operations. Torsional loads should be allowed to develop during coiling operation by preventing rotation of the jumper termination around its axis and the orientation of the jumper termination during coiling shall not change.

The jumper shall be coiled in the 3 turn figure eight pattern with recommended R and D dimensions. After completion of the third turn, the jumper termination can be positioned in the horizontal orientation for verification of the uncoiled length (L). Then the jumper shall be uncoiled and laid out straight. The coiling and uncoiling operation shall be repeated.

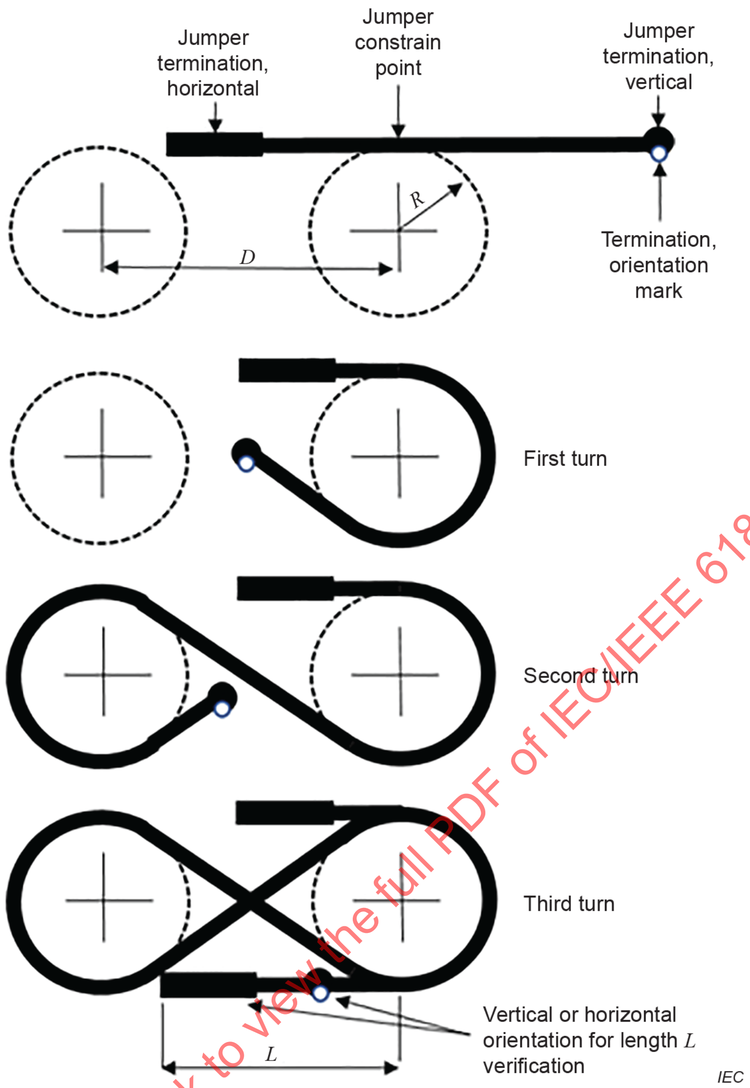


Figure 1 – Jumper handling simulation test

13.6.3 Acceptance criteria

Any damage to the jumper, hose terminations if used, cable and cable termination shall be observed and documented. Impact of the damage on the performance of the jumper shall be evaluated and acceptance justified. If a fluid filled hose is being evaluated, the pressure in the jumper hose shall not exceed design pressure of the hose during entire test sequence. The acceptance criteria for each of the tests are defined in the subclauses that are referenced in Table 37.

13.7 Jumper simulated deployment test

13.7.1 Objective

This test is to simulate deployment of the jumper assembly and verify that cable management allows sufficient free movement of cables to accommodate changes due to expansion and contraction of the jumper during pressure changes. The test requirements are given in Table 38.

13.7.2 Sequence

Prior to performing the hyperbaric testing of the jumper, the assembly shall have completed all production leak testing.

With the test pressure vessel dry, two bulkhead connectors shall be mounted on the pressure vessel flange and the jumper assembly mated.

During this test, the following parameters shall be recorded at each hold point within the pressure cycling sequence;

a) contact resistance;

b) insulation resistance.

Test media for step 5 to step 14 shall be according to Table 8.

Table 38 – Jumper simulated deployment testing

Step	Test	Test level	Reference
1	Contact resistance, atmospheric pressure	See test method	14.2
2	Insulation resistance, atmospheric pressure	See test method	14.8
3	PD test, atmospheric pressure	$1{,}73 \cdot U_0$ (10 pC)	14.5
4	Measure hose pre-charge pressure if applicable		
5	Submerse in environmental media, atmospheric pressure	Soak for one hour	
6	Increase pressure from atmospheric pressure to 1,1·RAP		
7	Allow to soak for 1 h at 1,1·RAP		
8	Contact resistance	See test method	14.2
9	Insulation resistance	See test method	14.8
10	Decrease pressure from 1,1·RAP to atmospheric pressure		
11	Allow to soak for 1 h at atmospheric pressure		
12	Contact resistance	See test method	14.2
13	Insulation resistance	See test method	14.8
14	Repeat step 6 to step 13 a further 4 times		
15	PD test	$1{,}73 \cdot U_0$ (10 pC)	14.5
16	High voltage AC test	$2{,}50 \cdot U_0$ (1 h)	14.6
17	PD test	$1{,}73 \cdot U_0$ (10 pC)	14.5
18	Measure hose pre-charge pressure if applicable		

13.7.3 Acceptance criteria

For jumpers utilising fluid filled hoses, both the pre- and post-test pre-charge pressure measurements shall be greater than ambient atmospheric pressure. The acceptance criteria for each of the tests are defined in the subclauses that are referenced in Table 38. There shall be no ingress of the test media in to the jumper.

14 Test procedures

14.1 Helium leak test

14.1.1 Objective

The helium leak test is to verify that all sealing barriers are correctly fitted and do not leak.

14.1.2 Method

A detailed test procedure shall be provided, describing how each barrier shall be tested. The procedure shall be supported with drawings defining each sealing barrier.

Helium shall be applied so that it fills one side of the sealing barrier/termination chamber to be tested. Helium leakages shall be sensed on the other side of the sealing barrier/termination chamber with a helium gas leak detector having an accuracy better than 10^{-9} mbar l/s. The room temperature and helium gas pressure shall be recorded continuously.

An outline procedure shall be as follows.

a) Connect the test equipment on one side of the sealing barrier/termination chamber to be tested and let the test equipment run until the background helium level indication is stable and low enough to allow reading in the acceptance criteria range.

b) Purge with helium systematically at the other side of the sealing barrier/termination chamber to be tested, where it shall be assured that helium fully surrounds each seal.

c) The helium leak rate before and after each purging shall be recorded.

NOTE Correct use of helium vacuum techniques will reveal a single seal leakage almost immediately, after a short period of helium purging (typically < 1 min). If helium is exposed for longer periods (typically > 5 min), diffusion through soft materials (seals, membranes, non-metallic parts) can take place – which would then complicate the interpretation of test results. A test procedure that caters for diffusion effects and includes test equipment with short supply/return lines contributes to a successful test performance. When testing across a double/multi seal barrier or double/multi string welded seam, a leak indication will be delayed – and it could be very difficult to discriminate a leak from diffusion.

If the use of helium vacuum technique is not possible due to the design, alternative helium leak test methods may be applied further to documented equivalence with relevant recognised international standards.

14.1.3 Acceptance criteria

The reading shall not increase with more than $5 \cdot 10^{-8}$ mbar l/s during purging with helium.

14.2 Contact resistance test

14.2.1 Objective

This test is to determine the resistance of the connector assembly.

14.2.2 Method

The contact resistance shall be measured at each contact interface during the assembly. The resulting total resistance (cable termination to cable termination) shall also be measured for all connector assemblies. The values measured during the prototype manufacturing acceptance tests and the initial test after manufacturing shall be used as references for all subsequent tests. The CR test shall be performed in accordance with IEC 61238-1-3. The current used in the test shall be 10 % of the rated RMS current but shall not be lower than 10 A. Any subsequent increase in contact resistance that is experienced during the type test programme shall be explained.

The contact resistance shall be measured and documented at each contact interface together with the total resistance of the connector assembly (cable termination to cable termination).

14.2.3 Acceptance criteria

a) Individual contact interface: The contact resistance at each contact interface should be such that when passing a rated current (RMS AC) the voltage drop across the contact interface shall not exceed 20 mV (extrapolation of the voltage drop measured during the test to the rated current is acceptable).

b) Resulting total resistance (cable termination to cable termination) in subsequent type testing: maximum ±10 % change from the reading taken at the start of the sequence.

14.3 Shell continuity test

14.3.1 Objective

This test is to determine the resistance between connector assembly metallic housings, intended to provide electrical continuity when mated.

14.3.2 Method

Testing shall be performed in accordance with IEC 61238-1-3.

14.3.3 Acceptance criteria

Maximum 100 mV voltage drop across each contacting interface with applied current of 10 A.

14.4 Screen continuity test

14.4.1 Objective

This test is to determine the resistance between the power cable screen and the connector/penetrator assembly, intended to provide electrical continuity (defined path for charging/fault currents).

14.4.2 Method

Testing shall be conducted in accordance with IEC 61238-1-3.

Two types of measurement shall be made:

a) cable screen to connector/penetrator;

b) cable screen to cable screen, either side of the mated connector.

14.4.3 Acceptance criteria

Acceptance criteria for each of the two tests:

a) maximum 20 mV voltage drop across each contacting interface with applied current of 20 A;

b) as for a), with added voltage drop for the additional contact interfaces/shell resistances – as specified by the manufacturer.

14.5 Partial discharge test

14.5.1 Objective

This test is to determine that the PD level for the connector assembly is within the acceptance criteria, and hence verify the insulation quality of the connector assembly.

14.5.2 Method

The test shall be performed on each circuit with the voltage applied between the cable conductor (pin) and the earthed metallic screen and housing, with all other circuits earthed. This procedure shall be repeated on each circuit. The partial discharge test shall be performed in accordance with the procedures outlined in both IEC 60270 and IEC 60885-3, alternatively as outlined in IEEE Std 386™.

– PD test at $1{,}73 \cdot U_0$: voltage shall be raised gradually to $2{,}00 \cdot U_0$ and kept at this value for 10 s before the voltage is lowered to $1{,}73 \cdot U_0$ and PD measurement is performed. Measurement time shall be 1 min.

– PD test at 2,50·U_0: voltage shall be gradually raised to 2,75·U_0 and kept at this value for 10 s before the voltage is lowered to 2,50·U_0 and PD measurement is performed. Measurement time shall be 1 min.

14.5.3 Acceptance criteria

PD level < 10 pC (peak) at 1,73·U_0.

PD level < 200 pC (peak) at 2,50·U_0.

14.6 High voltage AC test

14.6.1 Objective

This test is to verify the insulation level of the connector assembly. The test shall hence verify the electrical withstand level of the connector assembly and prove the ability to withstand the electrical stresses it is exposed to.

14.6.2 Method

The high voltage test shall be performed in accordance with both IEC 60060-1 and IEC 61442, alternatively IEEE Std 4™.

The test shall be performed on each circuit with the voltage applied between the cable conductor (pin) and the earthed metallic screen and housing, with all other circuits earthed. These procedures shall be repeated on each test circuit.

Test voltage and duration shall be as specified in the various test sequences in this document.

14.6.3 Acceptance criteria

No breakdown of insulation or flashover shall occur.

14.7 Impulse withstand voltage test

14.7.1 Objective

This test is to demonstrate the robustness of the connector assembly to withstand rapid transient over-voltages that may occur during switching or fault conditions. The test is especially relevant for applications where lightning over-voltages may occur (e.g. strike on a surface platform with short submarine cable).

14.7.2 Method

A standard lightning-impulse (1,2/50) withstand voltage (BIL) test, in accordance with IEC 60060-1 or IEEE Std 386 requirements, shall be conducted on connector assemblies with $U_m \geq 7{,}2$ kV. Unless otherwise agreed between the manufacturer and purchaser, impulse voltage peak levels shall be according to Table 39.

Table 39 – Impulse withstand voltage test levels

U_m (kV)	7,2	12	17,5	24	36
$U_{\text{peak, impulse}}$ (kV)	40	60	75	95	145

14.7.3 Acceptance criteria

No breakdown of insulation or flashover shall occur.

14.8 Insulation resistance test

14.8.1 Objective

This test is to measure the insulation resistance of the connector assembly.

14.8.2 Method

The insulation resistance against earth shall be measured on each electrical contact individually. All other electrical contacts and conductive parts shall be earthed. The insulation resistance shall be recorded after 1 min and 10 min. Test voltages are specified in Table 40.

For terminated connector assemblies, the insulation resistance shall be measured separately on the cable and connector/penetrator before termination. The individually measured values shall be the reference for the acceptance criterion for the terminated connector assembly, however not lower than 10 GΩ.

The test shall be performed at, or temperature corrected to, room temperature. Temperature correction shall be performed in accordance with ANSI/ICEA T-27-581/NEMA WC 53.

Table 40 – Insulation resistance test – Voltage test levels

Max system voltage U_m	Minimum test voltage
U_m < 7 200 V	2 500 V DC
U_m ≥ 7 200 V	5 000 V DC

14.8.3 Acceptance criteria

a) IR > 100 GΩ (stable reading) after 10 min for un-terminated connectors/ penetrators.

b) IR > 10 GΩ (stable reading) after 10 min for terminated connectors/penetrators.

14.9 Thermal shock test

14.9.1 Objective

This test is to verify that the connector assembly can withstand thermal shocks. These may result from deck storage, and insertion into sea water.

14.9.2 Method

The connector assembly shall be tested in its unmated condition, at atmospheric pressure. Three high temperature tests and three low temperature tests shall be conducted.

High temperature: The temperature of each connector assembly shall be raised to 60˚C and maintained for a period of four hours. The connector assembly shall then be cooled rapidly by immersion in water, which shall have a temperature between 0 °C and 5 °C. Water volume shall be sufficient to ensure a rapid cooling. Allow the connector assembly to return to ambient room temperature.

Low temperature: The temperature of each connector assembly shall be lowered to –25 ˚C and maintained for a period of four hours. The connector assembly shall then be heated rapidly by immersion in water, which shall have a temperature between 0 °C and 5 °C. Water volume shall be sufficient to ensure rapid heating. The connector assembly shall be allowed to return to ambient room temperature.

14.9.3 Acceptance criteria

The acceptance criteria for the subsequent verification tests specified in the applicable test sequence shall be met.

14.10 Thermal short circuit test

14.10.1 Objective

This test is to ensure that the connector assembly can withstand the rated thermal short-time current (I_{th}). There shall be no degradation of conductor contacts or insulation materials.

14.10.2 Method

The test method shall be as described in IEC 61442 for thermal short-circuit test. One end shall be connected to the test generator and the other end to a short-circuiting bar. The maximum short circuit temperature for the materials shall be defined by the manufacturer.

The connector assembly shall be subjected to two short circuits at the maximum permissible short-circuit temperature of the connector/penetrator and subsequent connected cable. The temperature shall be recorded continuously during the test. The time taken to raise the temperature from the starting temperature to the maximum temperature shall be recorded. The second short circuit shall be applied when the assembly has cooled to within 10 °C of the starting temperature prior to the first test.

14.10.3 Acceptance criteria

Any accessible contacts and insulation shall be inspected for any damage, especially thermal damage. An assessment shall be made during the final dismantling and examination. A calculation of the I^2t rating in accordance with IEC 61442 shall be made and recorded on the data sheet (Annex A).

14.11 Dynamic short circuit test

14.11.1 Objective

This test is to ensure that the connector assembly can withstand the rated dynamic short circuit current I_d without degradation or damage due to mechanical forces.

The test is a special test and only relevant if the peak current is above 80 kA (single phase) or 63 kA (three phase).

14.11.2 Method

The test set-up shall be representative for the installed system, in order to get representative forces between conductors. For 3-phase systems, the test requires a three-phase assembly as installed subsea, to be regarded as a valid test.

The test methods shall be as specified in IEC 61442. One end shall be connected to the test generator and the other end to a short-circuiting bar. The waveform shall be recorded.

The connector assembly shall be subjected to two short circuits.

14.11.3 Acceptance criteria

Any accessible contacts and insulation shall be inspected for any damage, especially thermal damage. An assessment shall be made during the final dismantling and examination.

14.12 Temperature rise test

14.12.1 Objective

A temperature rise test at rated current and frequency shall be performed before thermal cycling tests commence. The objective is to locate and determine the highest local temperatures within the connector assembly and to determine the current to be used for the thermal cycle test. For connector assemblies including some cable length, for example jumpers, any screen currents at rated conditions shall be included in the temperature rise test.

14.12.2 Method

Temperature sensors shall be attached to various locations on the connector assembly to enable monitoring of temperatures. Temperature sensors shall as a minimum be located as follows:

- ambient temperature;
- at the point where the highest local temperature is expected;
- at cable terminations;
- at the anticipated hottest spot on external surfaces of each accessible material type;
- as close as possible to the contact surface between male and female.

The rated current shall be applied and maintained until a stable temperature is achieved at each location being monitored. Thermal stability shall be deemed to have been achieved when two consecutive measurements of temperature taken at each location, within a 2 h period, do not differ from each other by more than 2 K. The rated current shall be maintained for a period of 1 h after thermal stability has been reached. The test current shall then be increased so that the temperature at the hottest location is increased to a stable temperature 5 K to 10 K above steady state temperature at rated current. The temperature rise test shall be performed

a) in air at ambient temperature, and

b) in the relevant operational environment (refer to Table 8) at the maximum ambient temperature (refer to Table 4). The current determined from this test shall be used as basis for the thermal cycles test (see 14.14).

In applications with screened cables, where the screens are earthed in both ends allowing a net screen current to flow, the screen current at rated conditions shall be applied to the screen during this test.

Electronic data storage or a chart recorder with a suitable number of channels shall be used to record temperature. Actual current values and voltage drop shall be recorded in parallel with each temperature measurement. All findings shall be recorded within the final type test report.

14.12.3 Acceptance criteria

The absolute temperatures measured for the different materials shall be below the relevant material temperature limitations.

This test is primarily a characterization test. However, acceptance criteria for absolute temperatures are necessary.

14.13 Extended temperature rise test

14.13.1 Objective

This test is to characterise the connector assembly with respect to current loading capability at various ambient temperature and frequency conditions. This may be necessary if there are to be full equipment integration tests in a topside environment where the normal cooling effects of sea water are not present. The test represents an extension of the temperature rise test in 14.12 and can be performed as part of this. The test is optional and shall only be performed if agreed between the manufacturer and purchaser.

14.13.2 Method

The extended temperature rise test shall be performed at conditions as agreed between the manufacturer and purchaser. Two possible methods for characterization are described below.

a) Method 1

Current carrying capability as a function of ambient temperature – given connector assembly operates at maximum allowed operating temperature. Results/graphs to be established for agreed frequencies. This is illustrated in Figure 2, where f_1 is the rated frequency, f_2 is another frequency and I_r is the rated current.

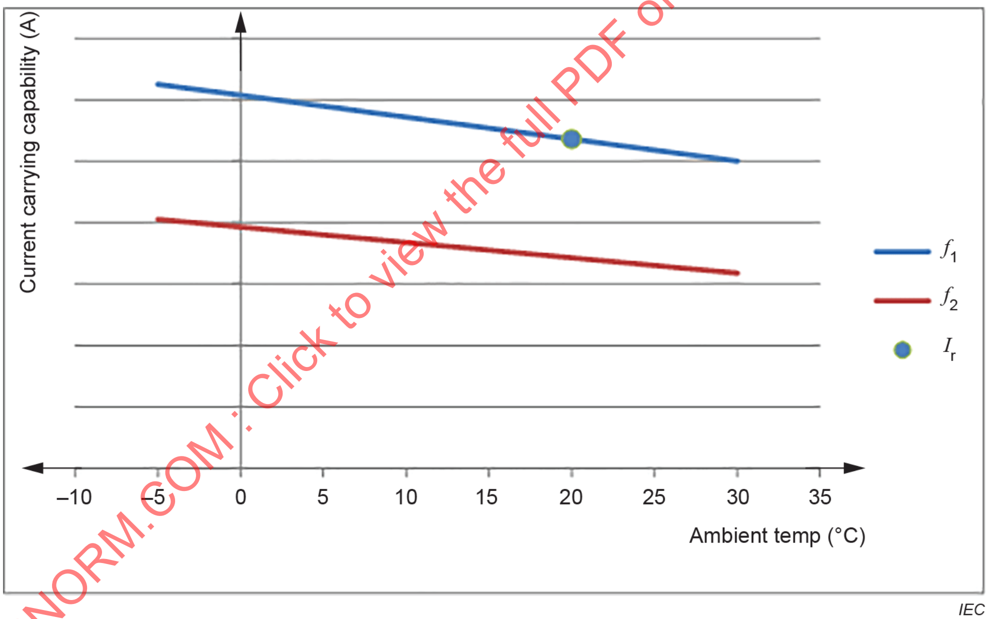


Figure 2 – Typical extended temperature test results, method 1

b) Method 2 (more comprehensive)

This method evaluates the connector assembly operating temperature as a function of operating current. Results and graphs shall be established for agreed ambient temperatures and frequencies. This is illustrated in Figure 3, where T_{a1}, T_{a2} and T_{a3} are three different ambient temperatures, f_1 and f_2 are two different frequencies, and T_{max} is the maximum allowable operating temperature in the connector.

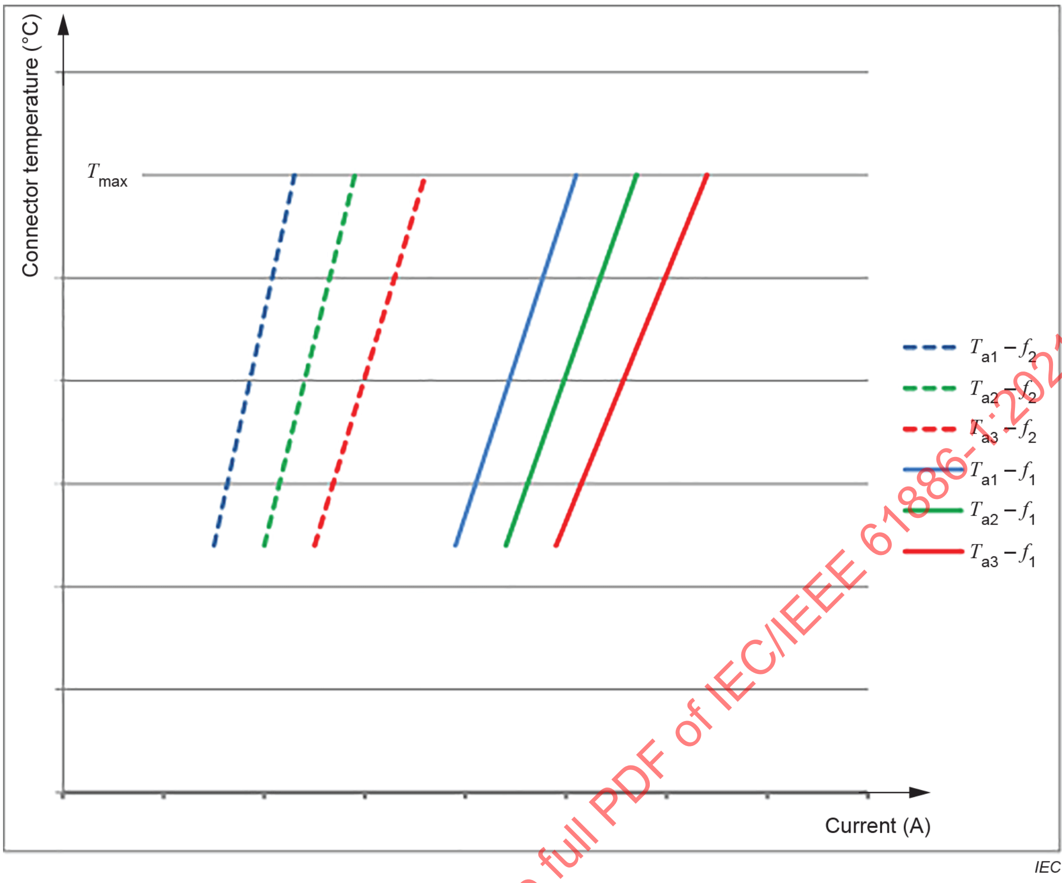


Figure 3 – Typical extended temperature test results, method 2

14.13.3 Acceptance criteria

This test is primarily a characterization test. The following acceptance criteria shall however apply: the absolute temperatures measured for the different materials shall be below the relevant material temperature limitations.

14.14 Thermal cycling

14.14.1 Objective

This test is to verify the ability of the connector assembly to handle load changes.

14.14.2 Method

The assembly shall be installed in conditions corresponding to the environmental fluid intended during operation or test media given in Table 8 and the worst-case operational thermal conditions according to Table 4.

The connector assembly shall be heated by passing the current (as determined by the temperature rise test in operational conditions – see 14.12) through the conductor. A voltage of 2,5 U_0 shall be applied continuously during the test. When the conductor temperature has reached a stable value – 5 K to 10 K above the temperature the connector assembly will have when running at maximum rated operational current –, it shall be kept at this temperature for at least 2 h. The connector assembly shall then be cooled down to within 10 K above ambient temperature. The total duration of each thermal cycle shall be a minimum of 8 h. Reference can be made to IEC 60502-4 and IEC 61442 (heating cycle curve).

Level of screen current in the cable terminations shall be assessed and accounted for if relevant.

It is not required to provide high power to the test circuit during this test. Current may be injected by means of low voltage, the current loop circuit can then be energized by a separate voltage source (line to ground) to 2,5 U_0 (current loop shall hence be insulated for this voltage).

14.14.3 Acceptance criteria

The acceptance criteria for the subsequent verification tests specified in the applicable test sequence shall be met.

14.15 Bending moment and free fall tests

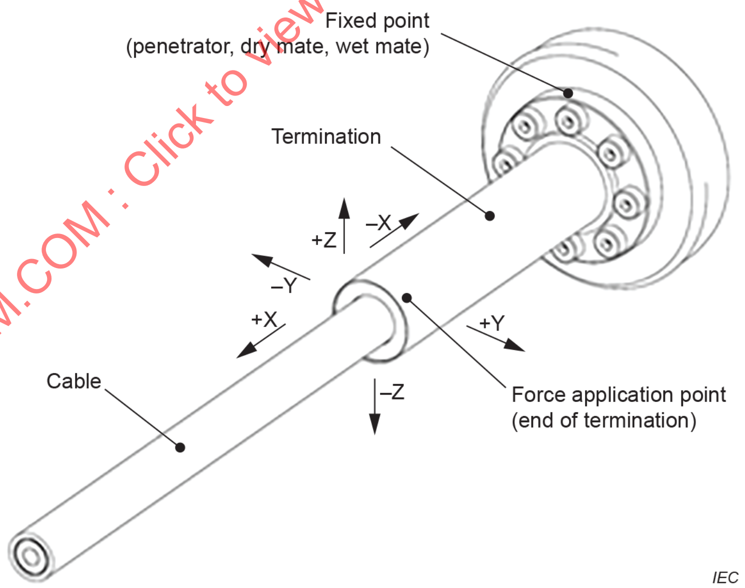
14.15.1 Objective

This impact shock test is to verify that the connector assembly can withstand an accidental mechanical load, without degradation or damage.

14.15.2 Method

a) A force of at least 2 kN shall be applied to the connector assembly (penetrator or mated connector pair), at the opposite end of the fixation point. The force shall be applied for at least one second before being removed. The test shall be performed in six directions along three mutually perpendicular axes, with a minimum of three applications of force in each direction. Refer to Figure 4.

b) A free fall test shall be performed in accordance with IEC 60721-3-2:2018, Table 5, class 2M5. The floor shall be hard, typically as for a transport compartment. For connectors, the test shall be performed with unmated connector halves and any protective devices installed. The test shall be performed in three mutually perpendicular axes.



For the +X and –Y direction, force shall be applied to the termination body. Force shall not be applied to the cable. Cable anchoring is being tested via the cable pull test.

Figure 4 – Bending moment test

14.15.3 Acceptance criteria

The acceptance criteria for the subsequent verification tests specified in the applicable test sequence shall be met.

14.16 Static pressure test – Penetrators

14.16.1 Objective

The static pressure test is used as a pre- and post-test verification test, and as a separate routine test.

14.16.2 Method

The test method for static pressure test for penetrators is given in Table 41.

Table 41 – Static pressure test – Penetrators

Step	Test	Test level	Reference
1	Contact resistance	See test method	14.2
2	Insulation resistance	See test method	14.8
3	Submerge in test media per Table 8	Soak for 1 h	N/A
4	Insulation resistance	See test method	14.8
5	Pressurise	From atmospheric pressure to 1,5·RDP Hold time 3 min	RDP = 10 bar for penetrators for pressure compensated equipment, both directions (Figure B.7/Figure B.8) For pressure retaining penetrators: RDP = RAP-1 for direction 1 (Figure B.3) and RDP = RAP-2 for direction 2 (Figure B.4)
6	Depressurise	To atmospheric pressure.	N/A
7	Pressurise	From atmospheric to 1,5·RDP Hold time 15 min	RDP = 10 bar for penetrators for pressure compensated equipment, both directions (Figure B.7/Figure B.8) For pressure retaining penetrators: RDP = RAP-1 for direction 1 (Figure B.3) and RDP = RAP-2 for direction 2 (Figure B.4)
8	Insulation resistance	See test method Undertake test after 1 min pressurised hold time	14.8
9	Depressurise	To atmospheric pressure	N/A
10	Insulation resistance	See test method Undertake test 1 min after depressurising Repeat test 1 h after depressurising	14.8
11	Helium leak test	See test method	14.1

14.16.3 Acceptance criteria

There shall be no evidence of leakage, and the test pressure shall remain stable throughout the test. Any variations in test pressure resulting from secondary influences (for example temperature) shall be explained and justified in the test report. The acceptance criteria for each of the tests are defined in the references listed in Table 41.

14.17 Extended static pressure test – Penetrators

14.17.1 Objective

This test is mandatory for penetrators exposed to production gas/fluids and demonstrates additional robustness. For other penetrators, the test is classified as a special test and shall only be performed if agreed between purchaser and manufacturer.

14.17.2 Method

The test procedure shall be as specified in 14.16, at the following pressure and temperature combinations:

- 1,5·RAP – y at maximum ambient temperature;
- 2,5·RAP – y at room temperature,

where y may be 1 or 2 depending on the agreed requirement.

14.17.3 Acceptance criteria

There shall be no evidence of leakage, and the test pressure shall remain stable throughout the test. Any variations in test pressure resulting from secondary influences (for example temperature) shall be explained and justified in the test report.

14.18 Combined pressure and temperature cycling test – Pressure retaining penetrators

14.18.1 Objective

This test is mandatory for penetrators exposed to production gas/fluids and demonstrates additional robustness. For other penetrators, the test is classified as a special test and shall only be performed if agreed between purchaser and manufacturer. When to perform the test in the test sequence is also subject to agreement between purchaser and manufacturer.

14.18.2 Method

The test shall be performed in accordance with ANSI/API Spec 6A:2018, F.1.11.3. Temperatures to be used shall be according to the extreme temperatures given by the temperature class (see Table 4).

Test media shall be according to Table 8.

14.18.3 Acceptance criteria

Acceptance criteria as specified in ANSI/API Spec 6A shall be fulfilled. Furthermore, there shall be no evidence of leakage and the test pressure shall remain stable throughout the test. Any variations in test pressure resulting from secondary influences (for example temperature) shall be explained and justified in the test report.

14.19 Shock and vibration test

14.19.1 Objective

This test is to verify that the connector assembly can withstand vibrations, without degradation or damage.

14.19.2 Method

The tests shall be performed such that amplifications built-up over time are registered, where gravity and mounting position shall also be catered for.